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A PHOTOGRAPHIC CATALOGUE OF NORTH POLAR STARS.

CAROLINE E. FURNESS.

FOR POPULAR ASTRONOMY.

A catalogue of stars within one degree of the north pole has recently been published by the Vassar College Observatory. This catalogue was compiled from the measurements of the photographic images found upon four plates, the centres of which coincided approximately with the north pole. The plates were taken with the 13-inch astro-photographic telescope belonging to the Helsingfors Observatory, after the manner prescribed by the permanent committee for the execution of the photographic chart of the heavens; that is, a réseau or squared network of lines was first photographed upon the plate but not developed, and the plate was then exposed three times to the sky, the telescope being moved slightly in declination between successive exposures. The lengths of the exposures were 6^m, 3^m, 20^s. Thus the brighter stars will have three images upon the plate, and the faintest stars only one. No star was included in the catalogue when only one image was present.

The plates cover a region of the sky two degrees square, so that each of the four under discussion contains the stars whose declination is greater than 89°, and a few additional ones lying in the corners of the plates outside a circle whose radius is 1°. They are not exact duplicates of each other for the telescope was turned in hour angle so that the hour circles forming the Y-axis are not the same for any two, but have been made to differ 45° in succession. The following figure shows the over-lapping of the plates:

It is proper to state here that these photographs were taken by Professor Donner of Helsingfors at the request of Professor Jacoby of Columbia University. They were measured at the Columbia Observatory and the measurements and the plates were put into my hands for reduction. Some necessary additional measurements were made at the Vassar College Observatory, where the entire reduction was made.

I will now give in outline the method of reduction and the results. The perpendicular distances of the images from the sides of the including réseau squares were measured, various instrumental corrections were applied, and the corrected rectangular

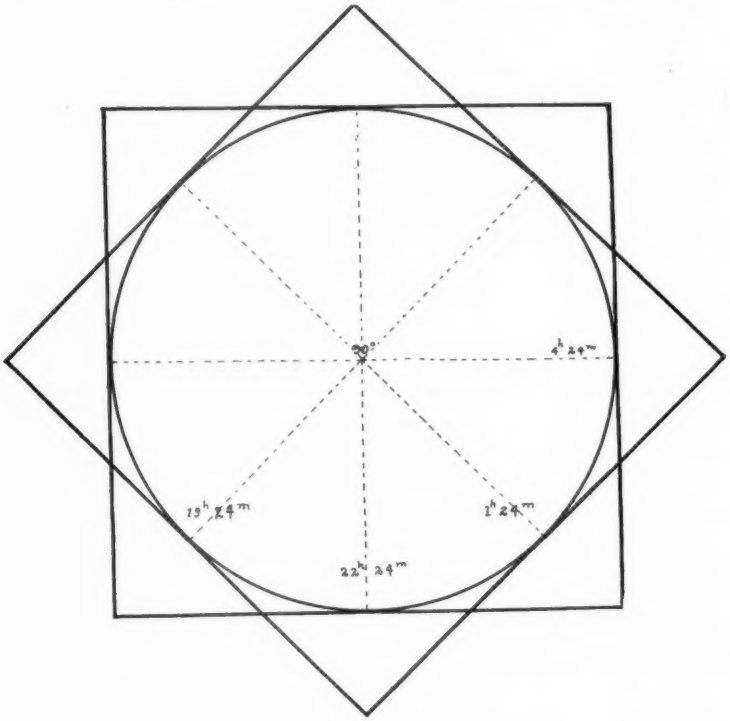

FIG. 1.

coördinates referred to the two middle réseau lines were finally obtained. These rectangular coördinates were then transformed into right ascension and polar distance by the following method:

Let X, Y be the rectangular coördinates of a star,

ξ, η be the rectangular coördinates of the point on the plate corresponding to the pole of the heavens.

A be the right ascension of the X-axis in the sky.

ω be the scale value.

α, π be the star's apparent right ascension and polar distance,

then from the figure we have the following relations:

$$p \sin B = Y - \eta, \qquad \rho \sin B' = -\eta$$
$$p \cos B = X - \xi, \qquad \rho \cos B' = -\xi$$
$$B'' = B' - B.$$

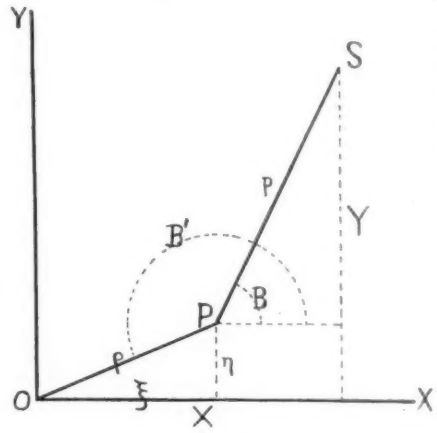

FIG. 2.

Now O the center of the plate, is assumed to be at the foot of the optic axis of the telescope, and it is therefore the center of the projection of the celestial sphere upon the plane of the plate. A plane angle whose vertex is at this point O is equal to the spherical angle of which it is the projection, but the plane angle B whose vertex is at some other point, as P, must receive a small correction in order to equal the corresponding angle in the sky. Fortunately, however, in the present case this correction may be neglected, since the pole is within 3′ of the center of the plate. A correction, s, of a similar nature must be applied to the linear distance p, in order to obtain the corresponding distance on the arc of a great circle. Hence the final equations for transforming the rectangular coördinates X and Y into right ascension and polar distance are

$$\left.\begin{aligned} \alpha &= A + B \\ \pi &= p\omega - \frac{1}{3}\rho^3 \omega^3 \sin^2 1'' - p\,(X\xi + Y\eta)\,\omega^3 \sin^2 1''. \end{aligned}\right\} \quad (1)$$

The equations (1) can be solved whenever we know the plate constants ξ, η, A and ω. On the other hand we can also obtain from them the values of ξ, η, A and ω if we know the right ascensions and polar distances of at least two stars, but as there are more than two known stars on each plate, the resulting equations can be solved by the method of least squares. And further since it is possible to obtain very close approximate values of these constants by a direct solution, it is sufficiently accurate to determine merely the corrections by means of least squares.

The known or standard stars were taken from Elkins "Heliometer Triangulation of Stars in the vicinity of the North Pole," which is published in the *Transactions of Yale Observatory*, Vol. I. The epoch of this catalogue is 1888.0, and hence in order to compare the star places with their positions as determined by equations (1) it will be necessary first to reduce the star places from the epoch of the catalogue to the date of exposure by applying precession, nutation, aberration, proper motion and refraction. We shall then be able to compare the computed and observed places for the same instant of time, and thus obtain the plate constants. This process is quite a long one for stars of such high declination, therefore it is abbreviated as much as can be without interfering with the accuracy of the results.

Precession and nutation do not affect the positions of the stars relative to one another, but merely change the planes of reference. Hence we are at liberty within certain limits to make a choice of the epoch which fixes the exact position of the pole, and if we choose the date of the catalogue for this epoch, we need apply only proper motion, aberration and refraction to the places of the standard stars, and then the constants ξ, η and A will fix the position on the plate of the pole of the epoch of the catalogue. The right ascensions and polar distances of the unknown stars computed from equations (1) will be their apparent places, referred to the pole and equinox of the catalogue.

The aberration formulas are due to Dr. Hill and are taken from the "Star Tables of the *American Ephemeris*." They involve $\odot$ the longitude of the Sun, and ϵ the obliquity of the ecliptic, both of which quantities are affected by precession. Therefore the longitude of the Sun was increased by the precession in longitude from 1888.0 to the time of exposure and for ϵ was used the obliquity of the ecliptic for 1888.0.

We can also make a simplification in the computation of refraction. The pole of the selected epoch may be treated as if it were a luminous point and subject to refraction, in which case the right ascensions and polar distances of all the stars will be affected by differential refraction only. This assumption is allowable because the point on the plate of which ξ and η are the coördinates is the projection of an imaginary point in the sky. Thus we are at liberty to select for the pole any point which is convenient, so long as we can connect it with the real pole by means of a rigorous relation. But precession affects certain quantities which appear in the formulas for refraction, *viz.*, θ, the

sidereal time or western hour angle of the vernal equinox, the vertex of which is at the pole of date; and z, the apparent zenith distance of the pole. Refraction formulas always contain some function of the hour angle of the star or $\theta - \alpha$, and it is at once obvious that we cannot connect these two angles thus unless they have the same vertex. Since we have adopted the right ascension for the epoch of the catalogue, we must transform θ into the same angle θ_0 which will have its vertex at the same point with α, *viz*, the pole of the epoch of the catalogue. The connection will be seen from the following figure:

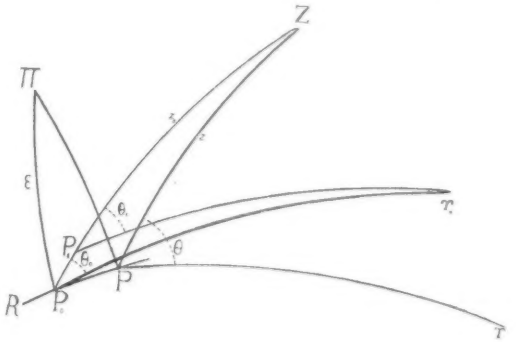

FIG. 3.

Let

P_0 = pole at epoch of catalogue,
P = pole at date of exposure,
P_1 = pole at epoch when refracted,
Π = pole of ecliptic,
Z = zenith,
$P_0\Upsilon_0$ = equinoctial colure for epoch,
$P\Upsilon$ = equinoctial colure for date,
$ZP\Upsilon = \theta$ = sidereal time of exposure,
$ZP_0\Upsilon_0 = \theta_0$, $ZP_1P_0 = \theta_1$,
$\Upsilon_0P_0R = A_0$, $\Upsilon PP_0 = A$,
$PZ = z$, $P_0Z = z_0$, $P_1Z = z_1$,
$\Pi P_0 = \epsilon$, $PP_0 = \pi$.

A is the right ascension of the pole of the epoch of the catalogue referred to the pole of the date of exposure, it is a little greater than 180°.

A_0 is less than 180°, and 180° + A_0 is the right ascension of P reckoned from P_0.

Employing a series developed by Jordan* we obtain these simple relations,

$$\theta_0 - \theta = \pi \,[\cos A \cot \epsilon + \sin (\theta - A) \cot z],$$
$$z_0 - z = -\pi \cos (\theta - A).$$

To find z_1 we have only to find the mean refraction for the zenith distance z_0 and apply it directly to z_0.

To determine A and π we may use the ordinary precession constants for the epoch t_0 of the catalogue, as follows:

$$A = 180^\circ + \frac{1}{2} m (t - t_0),$$
$$\pi = n (t - t_0).$$

With the auxiliary quantities thus determined the refraction in right ascension and polar distance will be found from the following equations:

$$\alpha - \alpha' = \kappa \sin (\theta_0 - \alpha') \cos (\theta_0 - \alpha') \tan^2 z_1,$$
$$\pi - \pi' = + \kappa \pi' [1 + \cos^2 (\theta_0 - \alpha') \tan^2 z] \sin 1''.$$

The derivation of these formulas is very interesting and will be found in a paper by Jacoby on the Pleiades, which is published in the *Annals of the New York Academy of Science*, Vol. VI, p. 253.

A general outline of the computation is as follows: first, select the standard stars for each plate, compute the aberration and differential refraction for those stars, obtaining thus their apparent places for the epoch of the catalogue; second, measure their rectangular co-ordinates and find from them by equations (1) the apparent places as observed from the photograph; third, comcompare the computed with the observed places and obtain the plate constants ξ, η, A and ω; fourth, with these plate constants solve equations (1) for all the unknown stars, securing by this process their apparent places referred to the epoch of the standard stars; fifth, apply to these apparent places, the differential refraction and aberration, and these final results will be the mean places referred to the epoch of the catalogue.

Each plate was reduced in the manner just described, and the means of the separate determinations of right ascension and polar distance taken from the final position. The catalogue contains sixty-five stars, forty-two of which appear on all four plates. The magnitudes range from 9.3 to 11.0. Thirty-five of the stars are found in Carrington's Redhill Catalogue of Circumpolar Stars, and thirty-four in the *Bonner Durchmusterung*.

* Jordan: *Handbuch der Vermessungskunde, dritte Auflage, 1890*, Vol., III, p. 313.

There are eight other plates taken at the same time covering the region from 89° to 88°. The reduction of these plates, together with a determination of the proper motion will form the contents of the next publication of the Vassar College Observatory.

Optical Distortion.

The results of this catalogue were used in investigating the optical distortion of the telescope with which the photographs were taken. It will be remembered that the telescope was turned in hour angle after each photograph was taken. The purpose of this change and its connection with optical distortion will now be stated. The photographic plate is inserted in the holder so as always to have a fixed position relative to the object glass, and the Y axis is always parallel to the same radius of the lens, hence the result of changing the hour angle is to place this radius opposite different hour circles and hence to cause the images of any one star to be in different sections of the four plates. If there is any displacement due to distortion in any other than a radial direction, this will be discovered by comparing the right ascension and polar distance of a star as found from one plate with its right ascensions and polar distances as found on the other three plates. For this purpose the four plates were reduced to a common standard by the aid of the forty-two stars which were found on all the plates. Then the right ascensions and polar distances of these forty-two stars were compared to see if there was any distribution of the differences from the mean. There appeared to be none, hence it was concluded that there was no appreciable distortion in the field of the Helsingfors telescope.

ATTRACTION AND THE FIGURE OF THE EARTH. II.

W. W. PAYNE.

In a previous article (p. 177, No. 74) we began the study of the figure of the Earth, calling attention to the views of scholars in early times regarding its shape or figure. It was thought that a brief historical review of some of the early opinions of thinking men might be useful in awakening interest in a most fertile theme that has occupied the attention of able scholars since "the time that the memory of man runneth not to the century."

We have spoken of how the first inhabitants of the Earth must have thought that its surface was, as it appeared, an extended plane whose extremities supported the vast dome of the heavens; "That the visible horizon was the boundary of the Earth, that the ocean was the boundary of the horizon, and that the Earth and heavens were the whole visible universe and all beneath the Earth was Hades."

The Chaldean view was peculiar in thinking that the Earth was shaped like a boat turned upside down, or, as we would now say, like the half of an orange with the flat side up. This opinion was held because they believed it to be proved by science as science was then understood. We also noticed some interesting things from Chinese sources, 800 years before Christ, about eclipses and the knowledge of these phenomena and what it would easily lead to in thinking of the shape of the Earth. Next came the views of the Greek philosophers from 640 to 400 B. C. in which were the studies of Thales, Anaximander, Anaxagoras, Plato and Aristotle, giving a curious, though natural, development of the earlier ideas of the shape of the Earth. First a great plane, then a solid of some unknown form, next a cylinder of greater length than breadth, until Plato's belief made it a cube, which possibly Aristotle changed into a spherical form, though of this belief on the part of Aristotle, we can not be certain. Some even think the supposition that he entertained such a view of the shape of the Earth is not warranted. Next we noted the influence of the scholars in Egypt on the growth of knowledge concerning the shape of the Earth. Here astronomy was cultivated at a very early date. It was believed by some that the spherical form of the Earth was understood by the Egyptians and the Babylonians before the time of Aristotle. If this be true it is more than probable that he knew the opinions of Egyptian scholars, for a large part of the science known in Greece came from Egypt where mathematics and astronomy were pursued more diligently and successfully than elsewhere in the East.

It was further noticed how Pythagoras, and others of his time in different countries gave forth certain views that lead us now to think that the scholars of those early times would be slow to publish their opinions because it was then so hard to prove them, against so much apparent truth to contrary. Those who did not believe in these new views of the shape and motions of the Earth would certainly demand very strong proofs in their support if the advocate was to have any hearing, any scholarly

support, or even any personal safety; for such views would antagonize the priesthood and that meant danger on the ground of crime against the civil power which was wielded with severe monarchial sway.

We are sure the student of history will be deeply interested in the unfolding of this idea of the shape of the Earth and the causes that have contributed to it. His interest will not be lessened in our loved science, when he sees the prominent part that it has played in unfolding a wealth of knowledge about the Earth that is now so familiar generally that a few persons, comparatively, doubt the main facts that the Earth is globular in form, and endowed with motions that are easily and plainly verified in elementary ways.

It is our purpose in the remainder of this paper to refer to what is called by some authors the spherical hypothesis of the shape of the Earth. This phase of the subject brings us to a time when the study of the figure of the Earth was undertaken by methods a little more in accord with the modern ways of scientific thinking. As a first step, thought seemed to be directed to the inequalities of the Earth's surface as compared with its size, the relation that mountains and valleys have to the figure of the Earth as a whole. As soon as the approximate diameter of the Earth was known it would be easy to get the relation of these elevations and depressions to the size of the globe as a whole, and so learn how irregular the external surface would be on account of them. It would be natural to think of the Earth as covered with water and then the smooth surface of sea-level would give a standard of reference for the real surface of our globe that could be determined definitely, for particular points of elevation or depression. It would be seen at once that the highest mountains and the deepest valleys would make no appreciable difference in regard to the general figure of the Earth. For the sake of illustration, suppose we have a globe 13 feet in diameter, and Mount Chimborazo were placed on its sea surface to a scale height of 21,424 feet, the elevation of its summit above the water level would be only one-tenth of an inch. A mountain about 4 miles high on a globe 8,000 miles in diameter would be as one-tenth of an inch to 13 feet nearly. It is like thinking of the roughness of an orange rind to the orange itself, when we consider the elevations and depressions of the surface of the Earth in the study of its general figure. They are inappreciable until we get further on in our investigation and try to learn

what is the more exact shape of the Earth, having determined that it is spherical, or somehow like a sphere.

The spherical idea seems to have been in the minds of Aristotle and Archimedes 250 B. C. (whether or not both believed in that as the form of the Earth) for they say the mathematicians estimated the circumference of the Earth as 300,000 stadia. The idea of trying some way to measure the dimensions of the Earth, to get a knowledge of its form and size, was certainly a great step in advance of what had been accomplished before. It would matter little how inaccurate first attempts might be, the fact that tangible evidence of kind and amount that all could study would surely, in time, lead to definite opinions regarding the correctness of the results reached by such methods. This is true of the work of Aristosthenes B. C. 230, who, probably, was the first to devise a method by which the length of the circumference of the Earth might be obtained. We do not know how well his value represented the true circumference of the Earth, because the value of his unit of measure, the stadium, is not now certainly known. As Professor Young says, in General Astronomy, p. 98, "there seems to have been as many different stadia among the ancient nations, as there were 'feet' in Europe at the beginning of this century." What Aristosthenes did to find the length of the circumference of the Earth and how he did it, are given, in brief but clear way, in General Astronomy as referred to above. The plan of his work, in general, was the same as that pursued at the present time. It consisted of two parts: (1) To measure the distance on the Earth's surface between two points in some unit of long measure, as feet or miles, which are terrestrial units, and (2) To measure the angular distance between the same points by observing the positions of the Sun or some other celestial object. It is at once seen that finding the distance between two points on the surface of the Earth is a geodetical problem; to find the angular distance between the zenith points in the sky corresponding to the terrestrial ones is purely an astronomical one.

When the observer has found the number of degrees that measure an angular distance in the sky, and the number of miles that measure an equal angular distance on the Earth, then he is able to tell how many miles are equal to one degree, and since there are 360° in the circumference of the Earth, he then knows the number of miles that equal the 360° or the circumference.

Aristosthenes made the circumference of the Earth 250,000 stadia; Posidonius, B. C. 90, found it to be 240,000 stadia;

Ptolemy, A. D. 160, made it 180,000 stadia. If we knew the value of each stadium used we could in these and other instances, compare results and ascertain somewhat closely the value of the work of each, if accidental errors are not taken into the account.

Another attempt was made in the year 819 to measure an arc of the meridian in Mesopotamia by astronomers of Bagdad, India. This work is noteworthy in one particular more than others, in that it was probably the first, or among the first, attempts to use wooden rods in the measurements on the Earth's surface. There is also some doubt regarding the result obtained by these astronomers, some claiming the work was not successfully completed, and others holding that the result obtained in this instance for the length of a degree was 56⅔ Arabian miles, which are equal approximately to 71 English miles.

We come now to a time when the interest in all work of this kind was abruptly stopped. The social storms that raged more or less steadily for 700 years in Europe, so overwhelmed all interest in scientific thought and speculation that nothing was done to keep what had been gained, much less to advance knowledge in any such way until the beginning of the 15th century.

As we now look back across this dark gulf of the middle ages, and think of the train of sad consequences from the terrible struggle that swept over Europe during this period, no one can wonder that almost everything that had been gained in art and science should be lost. The old idea that the Earth was a plane again became the prevalent one, even in the minds of the philosophers who lived early in the 15th century. The scholars among the priests, so far as we can learn, were opposed to the ideas of motion, or of spherical shape of the Earth; and that the philosophers of this time should have favored the doctrine of a flat Earth is as hard to explain as it is to know how or why the navigators at that time should be the first to revive the notion of a globular Earth. We know how Columbus fearlessly advocated the spherical form of the Earth in the presence of Spanish royalty, and how his earnest and half-convincing arguments won for himself an unusual patronage from the King and Queen of Spain, for a long and perilous voyage over a vast and unknown ocean simply to prove the opinion of one man then only in the humble walks of life. That victory at the Spanish Court was justly an immortal one; and the thrilling chapters in the story of discovery and adventure that followed are almost household words in every American home.

After this the voyage of Magellan around the Earth gave such emphasis to the globular form of the Earth that the hypothesis was once more accepted and thinking men began work anew to find out its size.

In 1525 Fernel calculated the length of a degree by getting the difference in latitude between Paris and Amiens, and then measuring the distance between the two places by counting the number of revolutions made by his coach wheel. He found in this way that a degree was equal to 364,960 English feet.

Next we come upon what is now known as the first instance of the use of the trigonometrical method. In 1617 Willeboord Snell tried the plan of measuring the distance between two points by using a base line and triangles dependent on it, in which the principles of surveying were employed. This method has been the favorite one from that day to this. "Mr. Snell measured a base line on the frozen surface of the meadows between Leyden and Soeterwood." The angles of the triangles were measured by a quadrant whose radius was 5½ feet long. His result for the length of a degree was approximately 66.63 miles. Fernel's value for a degree was nearly equal to 69.56 miles to the degree. "In 1633 Norwood in England, using a method similar to that of Fernel found the length of a degree to be about 69.51 miles.

The means of finding the length of one degree of arc on the Earth's surface was not certainly improved nntil 1671, which was the time in which Ricard of France worked. Although the telescope came into use in 1610, it was not adapted to fine measurements in this problem until Ricard put spider lines in the focus of the telescope so as to get a far higher degree of precision in determining the exact position of points to be located, for the sake of measuring angles and distances accurately. He used the trigonometrical method and for a base line he chose a distance of nearly seven miles which was twice measured with a degree of scientific precision which had never before been equalled. He was careful enough in this work to compute the errors of observation that would arise in consequence of his instrument being out of the center of his station when measurements were being made. He also had the advantage of a zenith sector, by which to determine the difference in latitude between the extremities of the arc of the meridian whose angular length he sought to know. His result was 69.76 unless for the length of a degree in latitude in northern France. This was the value that Sir Isaac Newton em-

ployed to verify his idea of gravitation with so much satisfaction on his own part.

It is interesting to astronomers now to notice how very closely the Ricard result comes to the later determinations in view of the fact that he knew nothing about the effect of the aberration of light on the place of the star in Cassiopeia that he observed; nor of the effect of refraction of the atmosphere on the ray of light passing through it, nor of the error of the star's place due to nutation at the time of his observation.

In this way and in others essentially similar, the students of these early times came to believe that the earth was nearly or quite a sphere, and so supposed that the degrees of latitude were about the same everywhere on the Earth's surface.

We will next time consider some of the steps leading from the supposed spheroidal form of the Earth to that of the ellipsoidal one.

ON THE ADJUSTMENT OF THE EQUATORIAL TELESCOPE.*

Second Part.

KURT LAVES.

For Popular Astronomy.

The following observations were taken with the modern $6\frac{1}{2}$-inch equatorial of the Students Observatory, University of Chicago. The sidereal chronometer Bröcking 1250 was used, the correction of which was $= +29^{s}.0$. The declination circle can be read to $1'$, the hour circle to 5^{s}, the two verniers for each circle are designated by *A* and *B*. It was the intention to make two complete lists of observations, one in the meridian in declination as well as in hour circle, and another in the $6^{h}-18$ circle. Owing to unfavorable weather only the $6^{h}-18$ circle set was completed. Still the number of equations obtained is sufficient to derive from them the instrumental constants.

1900, November 8th, Chicago, $\phi = 41^{\circ}\ 47'.4$, Observer K. Laves.

Name of Star	D_A	D_B	Time.	Position.	No.
	°	°	h m		
γ Aquarii	$-$ 1 50.5	$-$ 1 51.0	22 15.4	C. P.	1
	$-$ 1 50.5	$-$ 1 51.5	22.4	C. F.	
α Lacertæ	49 47.5	49 47.5	28.4	C. F.	2
	49 48.0	49 48.0	33.6	C. P.	

* Continued from page 540 of Popular Astronomy.

Name of Star	T_A	T_B	Time.	Position.	No.
	h m		h		
ϵ Ursæ Min.	18 4 12.5	6 3 55	22 56 50.5	C. P.	3
Groombr. 944	18 1 57.5	6 1 30	23 34 40.5	C. F.	4
ψ' Draconis	18 4 30	6 4 15	23 46 8.0	C. P.	5
δ Ursæ Min.	18 11 12.5	6 11 2.5	0 9 7.5	C. P.	6
	T_A	T_B	Time.	Position.	
33 Piscium	11 59 5	23 58 55	23 57 58.5	C. P.	7
	24 4 55	12 4 39	0 4 25	C. F.	
6 Ursæ Min.	24 12 40	12 12 25	0 15 13.5	C. P.	8

Clouds.

$\Delta\theta = +\ 29^s.0$ is not yet applied to the observed times.

The observations were made with a new filar micrometer with position circle. For the observations in declination (stars 1 and 2) the object was placed with the slow motion screw in declination on the fixed wire which had the direction of a parallel circle. The observations in hour angle were made as transit observations over the fixed wire, which was placed for this purpose perpendicular to the foregoing position (by means of the position circle).

The positions of the stars were taken from the *American Ephemeris* (pages 392, 393, 377, 374, 360, 339, 322, 320).

	α App.	δ App.	$\tau = \theta + \Delta\theta - \alpha$	$\tau - T$
	h m s	° ′	h m s	m s
1	22 16 33	— 1 53.0	— 0 1	
			+ 0 6	
2	22 27 14	+ 49 46.8	+ 0 1	
			+ 0 6	
3	16 55 55.8	+ 82 12.2	6 1 23.7	— 2 39.8
4	5 30 28.8	+ 85 8.6	18 4 40.7	+ 2 57.0
5	17 43 38.5	+ 72 12.1	6 2 58.5	— 1 24.0
6	18 3 54.4	+ 86 37.1	6 5 42.1	— 5 25.4
7	0 0 17.3	— 6 15.6	23 58 10.2	— 0 50.8
			0 4 36.7	— 0 10.3
8	12 13 44.1	+ 88 14.6	12 1 58.4	— 10 33.6

With ϕ and τ and δ given for each star the quantities like $tg\ \delta$, sec δ, sin ϕ $tg\ \delta$ and so on, which appear on the right sides of equations (a) and (b) were computed for each star. Their values will be found in the equations which follow later on.

In the formulas (a) and (b) it is necessary to correct the observed quantities D and T for the effect of refraction. From the following table the correction for refraction can be computed:

		Equation for z the zenith distance.	Refr. for Declination.	Refr. for Hour-Angle.
ad (*a*)	Upper Culm.	$z = \phi - \delta$	$-\mu \operatorname{tg}(\phi - \delta)$	0
	Lower Culm.	$z = 180 - (\phi + \delta)$	$-\mu \operatorname{tg}(\phi + \delta)$	0
ad (*b*)	6^h circle	$\cos z = \sin\phi \sin\delta$	$-\mu \operatorname{cotg}\delta$	$+\mu \frac{\operatorname{cotg}\phi}{\sin\delta\cos\delta}$
	18^h circle	$\cos z = \sin\phi \sin\delta$	$-\mu \operatorname{cotg}\delta$	$-\mu \frac{\operatorname{cotg}\phi}{\sin\delta\cos\delta}$

The value of μ can be taken from the following table where μ is expressed in seconds of arc:

App't z. °	log. μ.	App't z. °	log. μ.
0	1.7603	65	1.7580
5	1.7603	70	1.7566
10	1.7603	71	1.7561
15	1.7603	72	1.7556
20	1.7602	73	1.7551
25	1.7602	74	1.7544
30	1.7601	75	1.7535
35	1.7601	76	1.7525
40	1.7600	77	1.7513
45	1.7598	78	1.7498
50	1.7596	79	1.7478
55	1.7593	80	1.7453
60	1.7588		

(*a'*) *Discussion of the equations based upon the measurements with the declination circle in the meridian.*

*	$D = \frac{D_A + D_B}{2}$ ° ′	Refraction. ′	
1	− 1 51.6	− 0.9	C. P.
	− 1 51.4	− 0.9	C. F.
2	+ 49 47.6	+ 0.1	C. F.
	+ 49 48.1	+ 0.1	C. P.

$$-1'.4 = \quad \Delta D - \xi - 0.69e$$
$$-1\ .6 = -\Delta D - \xi - 0.69e$$
$$-0\ .8 = -\Delta D - \xi + 0.14e$$
$$-1\ .3 = +\Delta D - \xi + 0.14e$$

from the equations for the first star we obtain $\Delta D = +0'.10$
" " " " " second star we obtain $\Delta D = -0\ .25$

$\Delta D = -0'.1$, the mean of these two values, agrees well with former more numerous determinations of this quantity.

From the system above it follows that $\xi = +1'.10$ and $e = +0'.36$ fulfill it satisfactorily.

(*a''*) *Discussion of the equations based upon the measurements with the hour-angle circle in the meridian.*

*	$T = \frac{T_A + T_B}{2}$			Refraction.	
	h	m	s	s	
7	23	59	0	0	C. P.
	0	4	47	0	C. F.
8	0	12	32.5	−1.3	C. P.

The refraction for star 8 was computed from a general formula not mentioned above, this was done because the star is very near the celestial pole, where special precautions are necessary.

$$7^a \quad -0^m\ 50^s.8 = \Delta T - 1.00c + 0.11n \qquad -0.11\eta + 0.67E$$
$$7^b \quad -0\ \ 10\ .3 = \Delta T + 1.00c - 0.11n \qquad -0.11\eta - 0.67E$$
$$8 \quad -10\ \ 32\ .3 = \Delta T - 32.64c - 32.62n + 0.28\xi - 32.62\eta + 21.00E - 0.21e$$

The arithmetic mean of 7^a and 7^b determines ΔT.

$\Delta T = -30^s.5 + 0.11\eta$, the co-efficient 0.11 being small, it will be seen that η proves also to be small, so that we may adopt $\Delta T = -30^s.5$.

(*b'*) *Discussion of the equations based upon the measurements with the hour circle in the 6^h — 18^h circle.*

*	$T = \frac{T_A + T_B}{2}$			Refraction.	$\tau - T -$ Refr.
	h	m	s	s	s
3	6	4	3.7	+32.9	−192.7
4	18	1	43.7	−52.4	+229.6
5	6	4	22.5	+15.2	−99.2
6	6	11	7.5	+75.1	−400.5

It will be noticed that the co-efficients of c, n and ξ in the four equations are very nearly the same for each equation. It will therefore be impossible to determine each of them separately from equations of this nature; all we can do is to find their sum. We introduce therefore $s = c + n + \xi$ and determine s from these equations as well as E, e and ΔT being known from our previous work. The equations are as follows:

$$(3) \quad -192.7 = \Delta T - 7.33s + 6.87E + 5.50e$$
$$(4) \quad +229.6 = \Delta T + 11{,}80s - 7.85E - 8.81e$$
$$(5) \quad -99.2 = \Delta T - 3.16s + 2.08E + 2.44e$$
$$(6) \quad -400.5 = \Delta T - 16.93s + 11.28E + 12.64e$$

Putting $\Delta T = -30^s.5$ and $e = +0'.36 = 1^s.5$ we obtain:

$$(3) \quad -181.5 = -7.33s + 6.87E$$
$$(4) \quad +262.9 = +11.80s - 7.85E$$
$$(5) \quad -83.2 = -3.16s + 2.08E$$
$$(6) \quad -400.4 = -16.93s + 11.28E$$

To solve this system of four equations with but two unknown quantities, we could form six different groups each of two equations and derive six different pairs of values for s and E. Taking the mean of these systems of six values we would obtain values for s and E which would best fulfill the entire system. There exists a method which leads to the most probable values of the unknown quantities with considerable less work than is entailed in the proceeding outlined before. It is the method of least squares. Applying it to our system we find

$$s = + 20^s.10$$
$$E = - 3^s.35$$

Since $s = c + n + \xi = + 20^s.10$

and $\xi = + 4^s.40 \; (= 1'.10)$

we have $c + n = + 15^s.70$

To find the value of η we use equation (8) into which we put the values of ΔT, ξ, $c + n$, E and e. We thus obtain

$$32.62\eta = 17^s.46 \qquad \text{or} \qquad \eta = + 0^s.53$$

This value agrees well with the value of η derived from an observation in the 18^h circle of the star α Camelopardis made also on Nov. 8. The declination of this star was measured and with the values of ΔD and e given above η was found to be $0^s.4$.

Finally c and n are found separately by combining the value for $c + n = 15^s.70$ and the value for $c - 0.11n$ as derived from equations 7^a and 7^b. Indeed we obtain

$$c - 0.11n = + 20^s.25 + 0.67E$$

or

$$c - 0.11n = + 18^s.01$$
$$c + n = + 15^s.24$$

We thus obtain from these two equations

$$c = + 17^s.74 \qquad n = - 2^s.50$$

The observations of Nov. 8th, 1900, have therefore led to the following values of the instrumental errors:

$\Delta D = - 0'.1$	$\xi = + 1'.10$	$c = + 17^s.74$	$e = 0'.4$
$\Delta T = - 30^s.50$	$\eta = + 0'.13$	$n = - 2^s.50$	$E = - 3^s.35$

On the determination of E not much confidence should be bestowed. Indeed it is found from the method of least squares solution that its probable error almost amounts to the value of E. It is very difficult to change the index arm for the hour circle, the setting screws of the vernier plate not being of sufficient length. This accounts for the relatively large value of ΔT.

On account of the large corrections for refraction which accompany the $6^h - 18^h$ circle observations in hour angle and on account of the fact that a reversal of the instrument is impossible in this posieion, it is advisable to prefer the hour angle observation in the meridian. The unfavorable weather conditions have made it impossible so far to compare the results reached in the discussion above with those from a complete set of observations in the meridian.

THE UNIVERSITY OF CHICAGO,
Nov. 13th, 1900.

TOTAL ECLIPSE OF THE SUN.*

CHARLES P. HOWARD.

FOR POPULAR ASTRONOMY.

All the projected jets, wings, etc., east and west of the Sun, were also composed of equally fine filaments, but these seemed long, like hairs in a horse's tail. They may, however, have been broken up into short lengths like the others. As to this I cannot say either way, as no time was taken to observe. I was surprised that nothing nebulous was seen anywhere.

Near the east and west limbs of the Sun, short jets both bright and dark, were very numerous and crossed each other at all sorts of angles; the impression being that this effect was due to perspective; the jets appearing short, because projected towards or away from the eye.

From each polar region over an arc of about 55° rose about 30 long slender pink streamers, that curved away to right and left towards the plane of the equator, in lines having a striking resemblance to those taken by iron filings scattered on a sheet of paper over a magnet. For perhaps 300,000 miles they all remained of the uniform width of about 5,000 miles, beyond which they gradually grew wider and fainter, until finally lost in the general pinkish tint of the background.

Those furthest from the poles had the greatest curvature and were the longest, reaching certainly to a distance of two-thirds of the Sun's diameter and perhaps further; but as to this I am uncertain.

The surface of each streamer, was a uniform flat tint of the

* Continued from page 554.

most beautiful rosy pink color. They showed no perspective of any kind, but appeared to lie in a plane at right angles to the line of sight.

When those at one pole only were attentively looked at, they had the appearance of the most perfect serenity, as if entirely independent of gravitation, or of any other force.

When those at both poles were seen at once it seemed as if their lines prolonged must be continuous through the Sun; the effect was then most wonderful. It seemed as if the Sun by some intense force was actually creating currents in the surrounding ether which passing from pole to pole and out into space were made visible in some preternatural way by these slender pink streamers. This view of the eclipse was perhaps the most impressive of all; it seemed as if the Sun could be seen actually exerting a grip on the universal ether and that it somehow or other was alive and at work. This effect cannot be represented on paper nor described. For some reason it seemed as if the connection between mind and matter was in plain sight. This sounds very absurd, but the effect was there, and I remember saying to myself, "this is what we'll see after we are dead."

But most conspicuous and wonderful of all, were eight slender white stalks having fan shaped tops, that rose from near each pole to a height of about 180,000 miles. All sixteen were exactly alike, except that the curvature of the stalks was a little greater in those farthest from the poles. Their uniform breadth was about 3,500 miles and each fan shaped top was nearly an equilateral triangle 20,000 miles on a side; the outer side, however, was about 1,000 miles shorter than the other two.

Those at each pole stood equally distant from each other about 75,000 miles apart.

They rose with gradually increasing curvature to right and left of the poles, and all apparently reached to exactly the same height.

Unlike anything else in the field of view they appeared self-luminous: the first impression being that each was glowing, because traversed by a current of electricity; but though carefully looked for, nothing resembling a brush effect could be seen, either at or beyond the fans. Their light was perfectly steady; not the slightest fluctuation being noticed. Their edges were as sharply defined as if made of metal, and their color, including the fans, was everywhere a uniform flat tint, without the slightest trace of shading. The sides of each fan and the two outer corners, were

as sharply defined as anything could be, but the outer edge seemed to shade off an almost imperceptible amount.

Closely observed their color appeared yellowish white like melted silver, against a pinkish back-ground, but just as the Sun came out, throwing a bluish light across the Moon's disk, they appeared pure white or bluish-white. Their luminosity was the same from end to end, and was about equal to that of the air, a few seconds after the Sun appeared.

Like the long pink streamers, they did not show any perspective, but seemed to lie in a plane at right angles to the line of sight.

In appearance they had a peculiar character, difficult to describe and unlike anything else I have ever seen. They did not look as if they were composed of matter, as did all the other objects seen in the corona, but as if they were glowing because traversed or excited by some force. They had a strong, solid look, as if they were there permanently. They also had a kind of vicious look as if their existence and peculiar shape was the expression of terrific power, and they actually gave the Sun the appearance of being a living creature with extended antennæ.

These objects being altogether the most remarkable feature of the eclipse, I devoted practically all my time at the telescope to their examination, and all the above statements regarding them have a considerable degree of accuracy. My order of procedure in examining them was this: After a general view of the corona as a whole, in which the sixteen stalks were seen, apparently taking part in the general action going on all around the Sun, I made a thorough examination of them in detail.

First, the upper left hand stalk (as seen inverted in the telescope) was carefully examined throughout its entire length, particular attention being given to the fan on its extremity. Then a careful comparison was made, of all the stalks at this pole, with each other. Then looking down, to see if the stalks observed at the other pole in the general view, were actually like them, I could hardly believe my eyes, when there, nearly a million miles away across the Sun's diameter, stood eight luminous stalks, exactly like them in every respect, each terminating in the same fan-shaped top, and plainly created by the action of the same wonderful force though separated by such a tremendous space.

Though looking back and forth several times, from one pole to the other, no difference whatever could be detected between the two sets.

I then carefully looked for others, but none could be found. There were no smaller ones, nor any half-formed, hazy or fainter ones, nor anything to indicate that the eight stalks at each pole, formed part of any progressive development.

Although the above description can give but a faint idea of the actual appearance of the corona, it may perhaps enable others to understand why, as already stated at the first glance through the telescope, the Sun appeared to be an enormous magnet, alive and hard at work, with the ether in action all around it, for

1st. The Sun seemed to be throwing out the attenuated filamentous matter in all directions, with a sort of vicious energy, then with an equally vicious energy, it seemed to seize it and compress it into the depths of the spheroid, preventing its escape.

2nd. This force seemed to have nothing to do with gravitation, but to be a polar force. The curves taken by all the forms, whether quiescent or explosive, except near the plane of the equator, had a strong resemblance to magnetic curves.

3rd. Somehow it seemed as if the Sun was possessed of a mind, concentrated upon doing these two things, and was compelling everything around it to work in harmony, to accomplish this end.

4th. The eight luminous stalks rising from each pole seemed part of this action; they gave the Sun the appearance of reaching out with glowing tentacles, to grasp the matter trying to escape and force it down towards the plane of the equator, and as already stated it was they more than anything else that made the Sun appear alive and gave it its terrible aspect.

5th. The numerous long slender pink streamers, rising from each pole and curving away to right and left, toward the plane of the equator, gave the effect not only of magnetism in the Sun but of currents in the ether, flowing through the Sun from pole to pole, and far out into space.

An equally fine, but somewhat different view of the corona as a whole, was obtained while examing the dark explosive jet near the south pole. While my attention was concentrated on this object, rather than on the quiescent pink streamers or white stalks, which were in the same line of sight; as has been already stated, many straight jets were for the first time seen, being thrown off by the Sun radially from the neighboring regions, to distances considerably beyond the spheroid, giving the Sun the appearance of being full of this peculiar filamentous matter under such enormously high tension as to be on the point of bursting.

In fact, the Sun had the appearance of blowing off, like a boiler blowing off steam. Some jets seemed to shoot off into space in straight lines, but others seemed acted on by an intense force, that bent them slightly away from the poles and toward the plane of the equator. This was the third remarkable view of the corona as a whole, that one found impossible to illustrate; the impression now was that the Sun must be the combination of an enormous comet and an enormous magnet, and that a gigantic struggle was going on between these two elements, the cometic matter bursting out of the Sun in all directions, trying to escape, while the magnetic force seized it and forced it towards the plane of the equator. For some reason the sixteen stalks also seemed to be part of the struggle and to be glowing white hot because of its intensity.

My first thought upon seeing these straight jets, was that fresh meteoric matter must be falling into the Sun from all directions and having its cometic matter evaporated and thrown off by the force that repells the tails of comets; in fact, the Sun actually looked like an immense comet throwing out tails in all directions; but in a moment, observing that all this explosive matter was composed of filaments seen with wonderful distinctness and that none of it was nebulous like comets' tails, it was obvious that this could hardly be the right explanation.

For the purpose of comparing the seeing at Winton, with that at other places, and to throw all the light possible on the structure of the corona, I will describe the only other two objects observed through the telescope.

The corona proved such a vast, complicated and absolutely unique object, that it was only necessary to give close attention to any part of it, for the most surprising and beautiful forms previously unseen, to at once become visible.

Just as I had finished the examination of the upper left hand stalk, my eye leaving it for an instant, caught sight of a forest of pale and dusky pink stems standing radially on the S. W. limb.

Apparently they were made visible by a hot pink reflection from the invisible surface of the Sun. While looking at them, the thing that impressed me most, was the almost inconceivably attenuated matter of which they must be composed, to thus stand on the surface of the Sun reflecting so little of its light.

The stems seemed cylindrical, with perfectly straight and parallel edges, except near the top where they suddenly arched or

broadened out with a concave curve, while at the same time gradually fading away and disappearing into the color of the background.

They had the most remarkable quiescent appearance; looking even more peaceful and serene than the long pink polar streamers. They seemed slightly shaded as if actually cylindrical, and appeared to stand back of one another like the trunks of trees in a forest.

They varied greatly, both in relative height and diameter, but were all of exactly the same type. None were higher than 75,000 miles nor lower than 25,000 miles. Their diameters varied at random between 3,000 and 10,000 miles. I did not notice how far they extended in either direction and they may have reached much farther around the Sun's circumference than shown in my drawings

Having finally completed the examination of the stalks at the lower or north pole, and with only 3 seconds of totality to spare my attention happened to be attracted by a small reddish glare overlapping the black disk of the Moon on its northwest limb.

This I at once recognized as a prominence out of focus. Being curious to see a prominence in its natural color, the focus was changed, but whether the eyepiece was moved towards or away from the object glass I cannot say, (but it must certainly have been away,) when a unique and beautiful prominence appeared consisting of a group of six or seven exceedingly fine red threads, all sparklingly bright, extending radially from the Sun to a distance of about 100,000 miles. The outer threads were about 40,000 miles apart at base and about 30,000 miles at top. All the threads were equally fine and bright, and of about the same length; and were full of short kinks, like the fibres of a rope that has been unravelled. They all slightly leaned across each other at random, and besides the short kinks, all were crooked; one of them much more so than any of the others.

These sparkling red threads were so fine that they seemed to have no breadth at all, except that due to irradiation. This apparent breadth was hardly appreciable, not more than one-fourth or one-fifth that of the stalks.

A very slight change of focus caused them to disappear entirely, their light expanding and blending with the pinkish tint of the background.

When this prominence was in focus, five or six other small prominences, north of the Sun's equator, before invisible, at once came into sight.

That the images of the prominences should be in a slightly different focal plane from the corona proper, was wholly unexpected, and I have not yet been able to satisfactorily account for t. It was, however, a positive fact.

When these prominences were sharply in focus, the corona was out of focus with all its fine detail gone, the white stalks alone remaining plainly visible, but distinctly out of focus. While the eyepiece was being moved in and out, to focus the thread-like prominence, I particularly noticed that the white stalks went in and out of focus exactly with the corona proper, and I remember, although no doubt of such a thing had up to this moment crossed my mind, being now forcibly struck by the fact that this was absolute proof that they formed part of the corona.

This thread-like prominence had been in sharp focus for only about one second, when the Sun appeared as a sparkling thread of white light, a little way above it. The air in front of and around the Moon then appeared illuminated with a bluish light through which the stalks looked bluish white (color of Vega).

As the increasing sunlight illuminated the air more and more, the light of the stalks (slightly out of focus) remained constantly the same, so that in about two seconds the air becoming as bright as they, they vanished from sight; drowned by the rising brilliancy of the atmosphere through which they were seen.

The thread-like prominence, however, remained visible for about three seconds longer, until the lengthening crescent of the Sun, extended over an arc of nearly 60° and its lower cusps cut through and beyond it. Then it too was overwhelmed, and the last of all these wonderful objects disappeared in the continually brightening air, and the eclipse was over.

POSITIVE PHOTOGRAPHY WITH SPECIAL REFERENCE TO ECLIPSE WORK.*

FRANCIS E. NIPHER.

During the last year the writer has been making an attempt to adapt the process of positive photography to service in the two solar eclipses which occur during the next two years. The unusual duration of the period of totality in both, makes them peculiarly favorable to the use of such a process. And while this

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will also be to some extent an advantage in securing negatives, still an over exposure is then always possible. When such over exposure is corrected by the use of a restrainer, the effect is to dissolve away the very details which the long exposure was intended to secure.

By great over exposure in the old sense of the word, and development in the light instead of in the dark room, no over exposure for positives is possible. The only limitation then is an under exposure, which causes the positive picture to fog.

The object of the present paper is to give the present condition of the process, and to request any who may be able to do so, to aid in so improving it, that the best results may be secured in these eclipses. There will be no other opportunity so favorable in the next generation.

Let the stop of the camera be set at No. 8 of the universal system. The ratio of the focal length divided by diameter is then

$$\frac{f}{d} = 4_1 \sqrt{n} = {}_1\sqrt{8} = 11.3.$$

If the object to be photographed is a landscape, consisting mainly of mid-summer foliage, and the plate be a fast plate, like the crown plate of Cramer, the exposure may be made two to four minutes in length. For the first attempt the latter interval is to be preferred. The exposure may be made as much longer as may be desired. It has been successfully tried with exposures of six and eight hours.

The plate is taken to the dark room and is best developed by the light of a strong lamp. If the exposure has been not over two minutes, the best result will be obtained by placing the bath between two strong lamps. Two Argand or Rochester burners with porcelain shades in contact or nearly so, with the bath in a position of strongest illumination between and below the shades, is an admirable arrangement. The bath should be cool at the start, and it should be in ice-cold water during the development. The bath being rather weak, the development will go on very slowly.

Various developers have been tried. Pyro has given very poor results, although the same bath would yield brilliant negatives in the dark room. By far the best results have been reached by the use of Cramer's hydrochinon developer, the formula for which may be found in every box of Cramer plates. The formula is:

SOLUTION No. 1.

	Ounces.	Grammes.
Water	25	1000
Sulphite of soda	3	126
Hydrochinon	½	21

SOLUTION No. 2.

	Ounces.	Grammes.
Water	25	1000
Carbonate of soda	6	252

The two solutions are to be mixed in equal parts, when used, and are to be diluted to from one-third to one-fifth strength. A few drops of ten per cent. solution of bromide will give brilliancy to the plate, but will not improve definition of details. The bromide may be left out.

In transferring the plate from the holder to the developing bath, it would seem to be somewhat better to turn the lamps down until the liquid covers the plate, but the light should then be turned on at once. When lamp-light is used this precaution is not very important. In fact the writer is inclined to say that such precaution is not then necessary. If the exposure has been too small, either from insufficient light on the object, or from insufficient time, such an exposure in the light-room is a decided advantage. It carries the plate farther from the zero condition, and materially improves the picture. The same result may be secured by turning the camera upon the sky after the usual exposure to the object has been made, and before the shutter has been closed. This sky-exposure may be for half a minute with a No. 8 stop, but should not exceed this. The following experiment seems to indicate that this sky exposure should be after rather than before the exposure to this object.

A white paper was pasted on a somewhat larger card of dead black. It was placed against a brick wall in sunlight, and with a cloudless sky. After a minute of exposure to the plate in the camera, the black card was quickly shifted laterally by a distance slightly greater than its width. This was repeated ten times in an exposure of ten minutes. On developing, the first of the ten exposures was somewhat more distinct than those which followed, but between the others no difference could be detected. The last minute of the ten was as effective as the second. But when the experiment is terminated at the end of the first minute, the image is very indistinct. It is evident that the subsequent exposure during the nine minutes served to make more distinct the image of the card made during the first minute. And since the plate seems to be somewhat more sensitive at first than it is later

in the exposure, it is better to utilize this part of the exposure in securing details of the object, rather than in fogging the plate beyond the zero condition. This difference of sensitiveness is not very marked. It is difficult to see any difference in the first three and the last three minutes of a six-minute exposure. This may be shown in an interesting way by the following experiment. The experimenter should preferably be dressed in light-colored clothing, and should train the camera on a grass-covered hill, which will serve as a background. Any other dark background will of course answer the purpose. After snapping open the shutter, walk to a point about 100 feet distant, the camera having been focused for that distance, and stand motionless for two or three minutes. Then step sidewise four or five feet and stand for an equal time. Then walk back and close the shutter. The two figures will seem practically alike if the sunlight has not changed, and the darker background will not appreciably show through them. The plate will show no trace of the motions, and the figures will be as clear and distinct as in a good negative.

Of course the same thing can be done in the ordinary negative process by so arranging the conditions that the time of exposure is sufficiently lengthened.

In order to make the positive photography as useful as possible, it is necessary to find a developer which will bring out a clear positive with as small an exposure as possible. It seems certain that it must differ from any developer used in ordinary photography. The method of restraining an over-exposed negative is known, in order that it may be developed as a negative. If we consider this plate as an under-exposed positive, how shall it be pushed along over the zero condition, and developed as a positive? To that answer may be given in part. It must be developed in the light. A poor negative may be developed in a lighted room, and a poor positive may be developed in a dark room. These are not the conditions which yield the best results.

The writer had great expectations of the developer used by Waterhouse for producing positives in the dark room with ordinary exposures. The formula for this developer, as given in various works on photography, is:

		Parts.
A.	Eikonogen	5
	Sulphite of soda	10
	Water	100
B.	Carbonate of soda	4
	Water	100
C.	Phenyl-theocarbamide	1
	Water	2000

For developing take of *A*1, of *B*2, of *C*1 and of a 10 per cent. solution of potassium bromide 1. If the contrasts are too strong, a few drops of ammonia may be added.

This developer was said to produce a positive in the dark room, with ordinary exposure. It was hoped that this urea salt either in the Waterhouse developer, or in some other, and with development in the light, might shorten the camera time very greatly.

When the exposure is normal for a negative, and the plate is developed in the dark room with this developer, it is found that a yellow to orange coloration appears in the shadows. If there are contrasts on the object, the high lights look as they do in an ordinary negative. The roof of a building and the sides lighted by direct sunlight appear as in an ordinary negative. Light and dark strips of slate will appear reversed. The sky is dark. The sides in shadow are of a yellow or orange color, sometimes almost red, and appear as positives. If the exposure is increased somewhat either by an increase in time, by stronger illumination of the object, or by using a larger stop opening, the coloration disappears, and the whole picture is seen to be a negative. A still greater exposure being made, the picture approaches, and finally becomes a zero result. Nothing develops on the plate. With a still longer exposure the picture is reversed, and a real positive develops. This picture can be developed in the light. This is not the case with the Waterhouse pictures. They look like positives, as any negative may be made to look like a positive but they should be called pseudo-positives. They are not due to a real reversal. They are, moreover, somewhat disappointing in appearance. It is only too evident that this Waterhouse process does not seem to be a very promising field for application to eclipse photography, although it presents some very interesting illustrations of different forms of silver.

The most promising field for investigation at present consists in the application of some transforming process to the film, after it comes from the camera, and before the picture is developed. Various oxidizing agents have been tried with different degrees of success. The most satisfactory of these oxidizing solutions is a mixture of nitric acid and potassium bichromate in rather dilute solution. There is no trouble in getting very satisfactory results with four minutes of exposure and a No. 8 stop. It seems very probable that by varying the proportions of this transforming solution, and perhaps varying the oxidizing agents themselves, such exposures as are now given in the negative process, may

yield good positives. The field open for experimentation along these lines is very wide. The degree of illumination while in the transforming solution, and the time interval for the transforming process, are involved. The desirability of perfecting these processes at the earliest possible moment, leads the writer to urge those who have had wider experience in photography to lend a hand in this work. If fine details can be secured in a positive with a camera exposure such as is now required for a negative, then certainly there is great reason to hope that by exposing a plate during the whole time of totality in the long eclipses which will shortly take place, we may hope to secure better results than the present methods can give. In positive photography there can be no over exposure. In negative photography, over exposure is an approach to a zero condition. In positive photography the zero condition has been passed.

October 24, 1900.

ASTRONOMICAL BOOKS FOR THE USE OF STUDENTS.

H. A. HOWE*

For Popular Astronomy.

In a short series of articles it will be our endeavor to give such information concerning the books mentioned that the reader may gain a fair idea of their scope and value.

During the past few years a large number of popular books on astronomy have appeared in England and in this country. One who is thinking of purchasing such for a library, or for private reading, feels quite bewildered by the wealth of material brought to his notice by advertisements in scientific periodicals. There are also many books which are no longer conspicuously advertised, because they are not new, which are of such sterling merit that attention should be called to them.

A few books written in foreign languages will be mentioned, since a reading knowledge of scientific French and German is frequently possessed by students, and may be used in acquiring information not readily obtained in English. It is a notorious fact that even books on science have a national bias. An American writer, for example, naturally magnifies the work of his scientific countrymen, because he is better acquainted with it

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than that of the German or French. Hence the reading of a foreign book freqnently brings to light facts otherwise unknown, and throws light on previous knowledge.

It is evidently impossible to make a complete list of those works which are worthy of commendation to students. But the writer hopes to avoid the mention of unworthy works, and to give quite an ample list of valuable ones. For convenience the books described will be divided into classes, though it will sometimes be difficult to determine in what particular class a given book should be placed.

Historical and Biographical Matter. A knowledge of the historical development of astronomy is quite essential to a proper appreciation of the subject. As it is the oldest of the sciences its development from the time when it emerged from the mists of antiquity to the present day is one of the most complete and instructive chapters in the intellectual history of man. Along with the historical works go biographical ones, which throw most valuable side-lights upon the progress of the science.

Descriptive Text-Books: When a student is pursuing an elementary course in descriptive astronomy text-books other than the one which he is studying will be found to be valuable for supplementary reading. For each author considers the topics of astronomy from his own mental standpoint and presents them in a manner which is modified by his personal bias. The presentation of a particular subject in one book may seem obscure to a given student, while its explanation in another book is luminous. To one author certain facts may seem to be of no great importance or interest, while another writer brings them into prominence.

General Popular Works. Works on popular astronomy frequently discuss quite fully topics which are barely mentioned in the text-books, and often do it in so attractive a manner that the reader acquires new knowledge with a minimum of effort. They also sometimes elaborate important and interesting subjects to an extent which is quite out of question in a school-text. Of late years many such books have been written by men who are well versed in astronomy, so that their statements are to be relied upon.

Hand-Books. There is a small but valuable class of books, which are not strictly popular, and are much too extensive for use in the class-room. Such hand-books contain a wealth of ma-

terial which is of great service in the study of special subjects; they also often contain tabulated data which one finds with difficulty elsewhere.

Monographs. There are small treatises on special subjects, which are not beyond the understanding of college students who have had, or are taking, good courses in descriptive astronomy. Such subjects are the Sun, the tides, Mars, spectroscopy, etc.

Telescopists' Manuals. Under this head we include books which certain lists of objects of interest in the heavens. Some of these contain directions for the use and care of telescopes. Others are star-atlases accompanied by lists of double stars, clusters, etc.

Text-Books on Mathematical Astronomy. Under this head we shall mention only those books which seem suitable for use with undergraduate students. The term "mathematical astronomy" is used to embrace practical astronomy and physical astronomy.

NOTE ON MULTIPLICATION.

ASAPH HALL.

FOR POPULAR ASTRONOMY.

If we wish to multiply a given number by 9 we can multiply it by 10 and subtract the given number. If we wish to multiply by 8, we may multiply by 10 and subtract double the given number. These known rules give easily the following symmetrical results:

$$1 \times 9 + 2 = 11$$
$$12 \times 9 + 3 = 111$$
$$123 \times 9 + 4 = 1111$$
$$1234 \times 9 + 5 = 11111$$
$$12345 \times 9 + 6 = 111111$$
$$123456 \times 9 + 7 = 1111111$$
$$1234567 \times 9 + 8 = 11111111$$
$$12345678 \times 9 + 9 = 111111111$$

$$1 \times 8 + 1 = 9$$
$$12 \times 8 + 2 = 98$$
$$123 \times 8 + 3 = 987$$
$$1234 \times 8 + 4 = 9876$$
$$12345 \times 8 + 5 = 98765$$
$$123456 \times 8 + 6 = 987654$$
$$1234567 \times 8 + 7 = 9876543$$
$$12345678 \times 8 + 8 = 98765432$$
$$123456789 \times 8 + 9 = 987654321$$

NEW VOLUME, NEW YEAR, NEW CENTURY.

W. W. PAYNE.

For Popular Astronomy.

Our title is a climax of singular kind. Its relation of ideas is plain, but the common point of beginning for all is rarely unique. The year 1900 has finished its course, and that of a new year and a new century have begun, and we write January, 1901. Eight volumes of Popular Astronomy have also been completed, and with this number the ninth one has started on its annual course, with a better prospect, we believe, than any of its predecessors. The last year has been one of peculiar trial. The office which has done printing for this and kindred publibations for nearly a score of years, signally failed for our work in November last, without notice or apparent good reason. As a consequence, it was necessary for us to buy a new office especially for this publication, that we should not be longer necessarily dependent on commercial printers for the work of this kind needed.

The November and the December numbers have already appeared in the new typographical dress from the new office and they speak for themselves. Some of our friends have been very kind and appreciative in the encouraging words they have given us, in the midst of this, the severest test that has come to us in a score of years past. No one knows the burden of selecting and procuring the printing material necessary to bring out scientific articles of almost every kind and grade, as such work should be done, who has not tried it once at least. We now have one mathematical article in hand that requires an astonishing list of "sorts" so-called, in order to set it. This we well understood, for we have had some experience in managing a printing office, but when we made our order for the supplies on a large type founder's company in St. Louis, we received only a fraction of it, the venders claiming that there mnst be some mistake about it, for they had never received such an order before. They could not understand why we wanted so many superior and inferior letters and figures, accents, prime marks and other varieties to match, in fuller detail than we care to enumerate. One can imagine a part of our disgust when this special type was examined carefully to find that only about one half of it could be used at all because of the way it was made. The different kinds used together would not look well in print, so part of it must go back to St. Louis to

be replaced by the proper kinds. This is only one of several lines of hindrance that have been besetting us during the last sixty days. Nevertheless we are again on time with our issue for this month, and expect other numbers to follow regularly in the future.

Our readers will understand from this reference to change of printing offices, why it has been impossible to send out proofs of articles to writers as usual, or to give the full variety of matter in each number as heretofore. This drawback in our work will not materially hinder us longer, but, we expect, on the contrary, to go ahead in a better way for the future. We, at least, now are full of hope on account of better facilities for doing this special work than have been within our reach previously. Our printing office will be supplied with the necessary type of all varieties, and experienced persons for the composition to bring out quickly and well all technical matter suited to the wants of advanced students in the study of astronomy.

The past year in our loved science has been one of quiet work along the old lines of research, but, in the newer lines, apparently it has been more general and systematic. What has been accomplished in the old and the new astronomies during the last twelve months will be given more particularly later, when the facts are gathered more fully that all may be stated more concisely.

When we think of the work in astronomy that has been done in the nineteenth century, the mass and quality of that which may be called excellent, or even good, is astonishingly great. It is a fitting time now to write the history of astronomy in the nineteenth century. As delightful as is that charming book by A. M. Clerke bearing the title of "History of Astronomy during the Nineteenth Century," it was written too soon to claim that comprehensive title fully. The work done in the century up to 1885 does show wonderful progress, and would busy a ready pen in its recital for all the space of a large volume although a decade and a half of its most noble years would be omitted when the end of 468 pages was reached as is true in the book above referred to.

Then astronomers did not have, and of course did not know how to use the rapid photographic plate. The eclipse work of 1889, so far as its photographic side is concerned, was little more than pure guess-work; for the quick, dry plate in its standardized form had just come into hand at this time, and no one knew how

confidently to expose it. Trials were made beforehand in evening light, in the hope of imitating the effect of the darkness of totality; but the trouble with these experiments was, the fact that few, if any, could foretell the degree of darkness that would attend the total phase. The result was, many negatives taken at that eclipse were worthless, but some were accidently good and a few unexpectedly fine. The pictures taken by the Harvard College Observatory expedition at Willows, Cal., in 1889 were excellent in showing the polar streamers of the corona. The St. Louis expedition obtained a fine photograph of the great streamers from the equatorial regions of the Sun, which showed in a beautiful way the curious structure of the corona in some of its most pronounced features, due probably to great solar activity in that part of the spot period. Other work of this eclipse might be mentioned in this connection, if we were aiming to give an account of the great step in advance at this time in the fertile field of astronomical photography. But this is not our purpose now. Somebody who is competent and willing to undertake the task will doubtless soon write a full history for the astronomy of the nineteenth century which is so much needed for ready reference.

For the year to come some things in mind regarding the management of POPULAR ASTRONOMY may be said at this time. It is our plan to have some special and useful themes treated, in the current volume, a little more fully than we have been able to do in the past. This seems to be needed by a large class of readers, who have been growing manifestly in their knowledge of astronomy and are desirous of more information along certain lines of study. We are aware that while we gain something in treating a theme in a series of articles for the sake of fuller and more complete statement of what may be said, we lose something by the monthly breaks that are necessary to the plan, yet on the whole the gain appears to be greater than the loss. There are some themes that cannot be broken in this manner without serious loss in the treatment. In such cases, though long, the articles will be presented without division.

We are fortunate in securing a series of articles from Dr. Herbert A. Howe of Chamberlin Observatory, University Park, Colorado, on "Astronomical books for the use of students," on this plan, the first in the series being given in this issue. Dr. Howe is a practical astronomer, a fine scholar in astronomy, and the author of a text-book on descriptive astronomy, and of another excellent popular book titled, "Study of the sky." We

know the forth-coming series will give our readers the latest and the best information known in the realm of books.

A thorough knowledge of mathematics is so necessary for advanced studies in astronomy that systematic work of this kind is now being considered. What we want is a series of articles covering the gronnd in the same general way as that so well indicated by Dr. Howe in his introduction already referred to. It is matter of the greatest moment that students who are not, and cannot, be under the immediate direction of a skilled instructor, shall have some help in the choice of mathematical books, and the order in which they should be pursued to gain the knowledge of mathematics that will serve best in later astronomical work.

The field of astronomy is now so large that one person will not attempt to become proficient in all parts of it. Such an undertaking is sure to fail. All the more is it needful in later years that ambitious students have the advice and the direction of those who are experienced somewhat at least in both mathematics and astronomy that they may start rightly, and afterwards lose as little time as possible in aiming at the right work before them.

Mr. J. A. Parkhurst will continue his thorough and scholarly work in furnishing current notes about the variable stars. It is due him to say, that his valuable services, in our opinion, have made our publication stand first in any country, so far as regular variable star work is concerned.

Spectroscopy will receive the careful, intelligent and discriminating attention of one fully competent to give the substance of work, as it progresses, in monthly notices which our readers have so much appreciated in the past. We can not commit this work to better aid than that which has served us so well in the past.

We are delighted to announce that Dr. Morrison of Washington will continue his series of articles in forth coming numbers, on subjects calculated to aid advanced students in astronomy who wish to pursue the topics belonging to the *American Ephemeris and the Nautical Almanac*. The next to appear is titled, "General Peturbations and the Perturbative Function, a continuation of the theme already begun. Those able to read Dr. Morrison's articles, at home and abroad, have expressed great appreciation of the aid he is so cheerfully giving them as they wrestle with this hard work.

I am sure I can say that Dr. Wilson and myself, on whom

falls the burden of the immediate management of this publication, will give to it our best thought and labor in the future, as we have striven to do in the past, in hope of having the same kindly and helpful patronage that has come to us in the past years. If we secure this, though the publication brings us no net financial returns, we will have been satisfied in believing that we have been aiding some one else to obtain a better knowledge of astronomy as the years go on.

DETROIT'S DIFFERENT KINDS OF TIME.

The amusing struggle that has been on in Detroit during the last few weeks between the advocates of standard time and Sun time, has unfortunately suffered an almost total eclipse, so far as the rest of the country is concerned, by the larger events in war, diplomacy and politics.

Not every one, perhaps, knows that Detroit has been clinging to Sun time, while every other important city in the land is using standard time. Thus, when it is noon in Chicago, it is 12:28 in Detroit; if standard time were in use in both places it would be noon in Detroit when it was noon in Chicago. Many Detroiters did not relish being out of step with the rest of the country, and on November 20 the council issued an edict that the city should adopt standard time. The next day there was great turning back of clocks. Then the question arose as to whether the factories, banks, churches, theatres, etc., should begin and close a half hour later, or whether they should run on a "split-hour" schedule, instead of beginning and closing on the even hours. To make it worse, many clung to the "Sun time," and by the end of the week every one in the city was wearing a worried look. The conviction finally dawned upon a large number of people that it was better to be in step with one another in Detroit even under the old time than to dislocate all their social and business schedules in trying to get into step with cities hundreds of miles away; and great pressure was brought to bear on the city council to reverse their decision. On November 27 they reversed, with the understanding that the question should remain open another week. Another week of what the Detroit *News* says was "perfect chaos in respect to the marking of time" reigned in the Michigan metropolis, and then the city council, on Tuesday evening of last week decided by a decisive vote to stick to Sun time. One of the "standard time"

aldermen derisively offered a resolution providing for the erection of a sun-dial in front of the city hall but, it was buried by referring it to the committee on sewers.

The State of Michigan, some years ago, adopted standard time as the legal mode of reckoning, and the Detroit *Journal* contends that this will compel a great number of commercial and legal transactions in Detroit to conform to standard time. It says further: "The action of the common council reconsidering and repealing an ordinance or resolution recognizing central standard time and authorizing city officials to conform to it, is void and invalid, since the common council has no authority, either inherent or delegated, to repeal state legislation. Standard time is the legal time of the city and county and will continue to be until the legislature changes the standard." The Midland (Mich.) *Republican* says: "Poor, halting Detroit is having a hard time with its time—more kinds of time than it knows what to do with. Only time can tell what it will do this time." The Sparta (Mich.) *Sentinel* facetiously remarks that "it would not be surprising if the old village returned to its first love, horse-cars, before spring.—*The Literary Digest*, Dec. 15, 1900.

ASTRONOMICAL PHENOMENA DURING 1901.

Eclipses.

There will be during the year 1901 two eclipses of the Sun, one of the Moon, and a Lunar Appulse.

1. A Lunar Appulse May 3. The Moon will pass through the penumbra of the Earth's shadow, almost touching the umbra on the south side. The northern portion of the Moon will thus be perceptibly darkened for a short time. The time of conjunction in right ascension, of the center of the Earth's shadow and the Moon's center will be $6^h\ 56^m\ 17^s.0$ Greenwich mean time, but the time of nearest approach of the Moon to the shadow will be at $6^h\ 30^m.8$, soon after the Moon has risen in England. The appulse will therefore not be visible in the United States.

2. A Total Eclipse of the Sun May 17. This is one of the most important eclipses of the new century, because of the long duration of totality, $6^m\ 26^s.8$ at maximum, but unfortunately it will not be visible on this side of the globe, nor in Europe, and but little of the path of totality crosses any land. The accompanying chart shows the regions where the eclipse will be visible, and from it the only available spots from which the eclipse can be observed on land are the islands of Sumatra, Borneo and New Guinea. The most favorable positions are in Sumatra and probably most of the observers who may be so fortunate as to be able to go to that distant part of the world will locate upon this island.

ELEMENTS OF THE ECLIPSE.

Greenwich Mean Time of conjunction in right ascension, May					17d	17h	28m	45s.3
Sun and Moon's R. A.	3h	37m	2s.49	Hourly motions	9s.93 and		153s.85	
Sun's declination	+19°	23′	49″.2	Hourly motion	+	0′	33″.6	
Moon's declination	+19	1	31 .5	Hourly motion	+	5	20 .9	
Sun's equa. hor. parallax			8.7	Sun's true semidiameter		15	48 .4	
Moon's equa. hor. parallax	60	58	.5	Moon's true semidiameter		16	36 .1	

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time			Longitude from Greenwich.		Latitude.	
	d	h	m	°	′	°	′
Eclipse begins	May 17	14	59.9	51	34.4 E.	20	21.9 S.
Central eclipse begins	17	15	57.6	40	11.2 E.	27	27.6 S.
Central eclipse at noon	17	17	28.8	96	51.9 E.	2	7.1 S.
Central eclipse ends	17	19	10.2	156	53.6 E.	12	49.0 S.
Eclipse ends	17	20	7.9	145	4.5 E.	5	38.0 S.

3. A Partial Eclipse of the Moon, Oct. 27, will not be visible in the United States, but will be visible generally throughout Europe, Asia and the Pacific Ocean. The beginning will be visible in Alaska and the end in the Eastern portion of Africa. Less than one-fourth of the Moon's disk will be immersed in the umbra of the Earth's shadow at the maximum of the eclipse.

4. An Annular Eclipse of the Sun, Nov. 10, will be visible as a partial eclipse throughout the greater part of Europe, Asia and the northern part of Africa. The path of the annulus is quite wide, the duration being 11m 2s.5 at maximum. It begins in the Mediterranean sea at the island of Sicily and passes southeastward across the city of Cairo in Egypt, across Arabia, the Indian Ocean, the point of the peninsula of Hindustan, the island of Ceylon, the Malay Peninsula and the southern part of Siam, ending on the island of Luzon of the Philippines.

ELEMENTS OF THE ECLIPSE.

Greenwich Mean Time of conjunction in right ascension, Nov.					10d	19h	18m	3s.2
Sun and Moon's R. A,	15h	3m	0s.48	Hourly motions	10s.12 and		121s.42	
Sun's declination	−17°	15′	41″.7	Hourly motion	−	0′	41″.9	
Moon's declination	−16	49	40 .8	Hourly motion	−	5	33 .8	
Sun's equa. hor. parallax			8 .9	Sun's true semidiameter		16	9 .6	
Moon's equa. hor. parallax	53	56	.0	Moon's true semidiameter		14	41 .1	

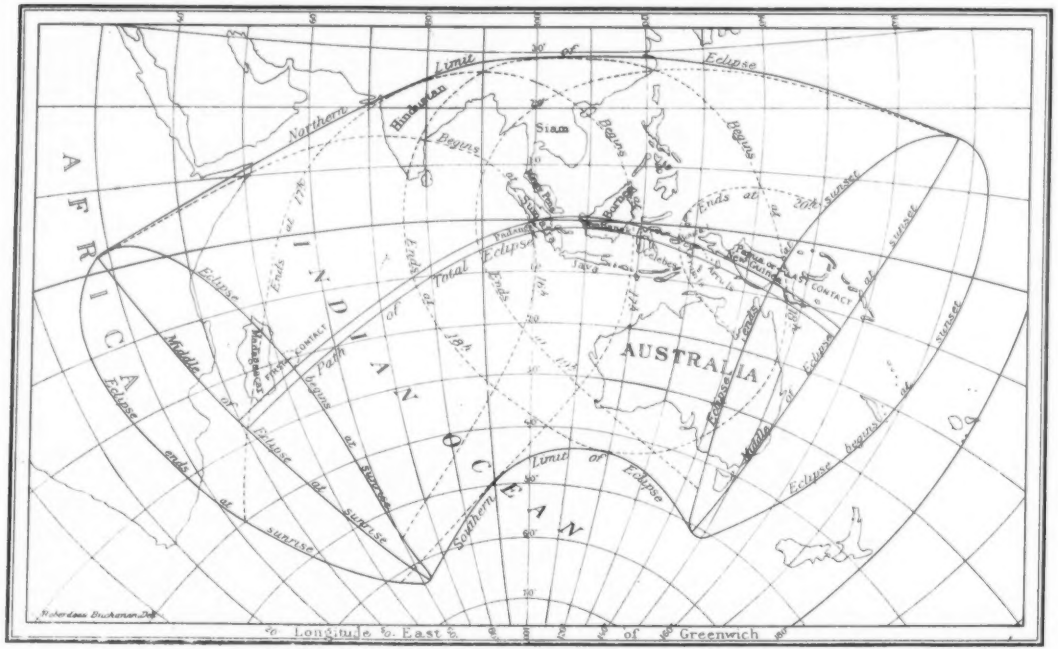
CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time.			Longitude from Greenwich.		Latitude.	
	d	h	m	°	′	°	′
Eclipse begins November	10	16	29.8	27	34.3 E.	26	46.0 N.
Central eclipse begins	10	17	43.7	13	34.0 E.	36	55.7 N.
Central eclipse at noon	10	19	18.1	66	29.9 E.	11	44.6 N.
Central eclipse ends	10	21	13.2	122	7.9 E.	17	20.8 N.
Eclipse ends	10	22	27.2	107	1.7 E.	6	59.8 N.

THE PLANETS.

The apparent paths of the major planets through the constellations of the zodiac during 1901 are shown in the charts Figs. 1, and 2. Mercury, it will be seen, begins the year in Sagittarius, and follows a smooth curve eastward until about the end of February, when it makes a large loop in Aquarius. This loop being completed during March the planet resumes a comparatively straight-away curve until the latter part of June, when another loop, the inverse of the first is

TOTAL ECLIPSE OF MAY 17TH 1901.



Note. The hours of beginning and ending are expressed in Greenwich Mean Time.

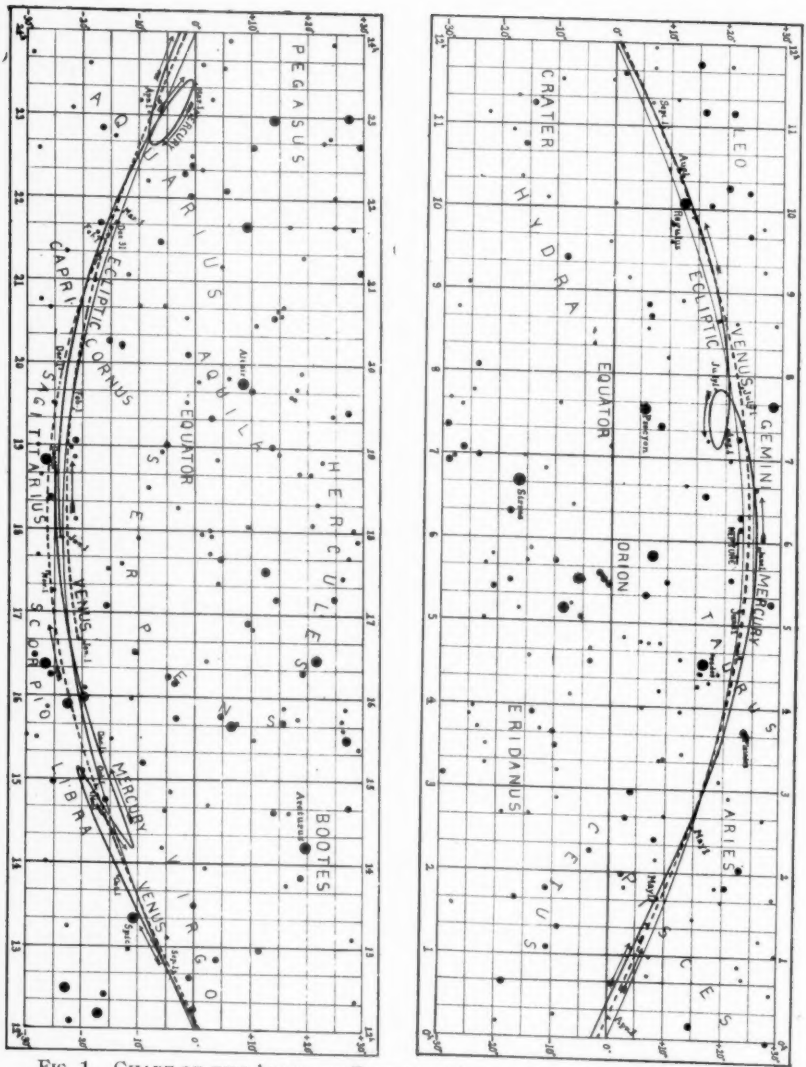


FIG. 1. CHART OF THE APPARENT PATHS OF MERCURY AND VENUS DURING 1901.

described in Gemini. In October and November the planet's path forms a great reversed *S* in Libra, after which its course is eastward for the remainder of the year, ending about ten degrees east of the point where it began.

Mercury will be visible as evening star in February, June and October, and as morning star in April, August and November.

The course of *Venus* during this year contains no loops, there being no retrograde movement. The planet will be morning star until April 30, when superior conjunction occurs. After that it will be evening star, seen higher and higher in the western sky at sunset until Dec. 4, when it will be at greatest eastern elongation, 47° 19′ from the Sun, and increasing in brilliancy up to the close of the year.

Mars retrogrades from the middle of January until the first of April, forming a large loop in Leo, then advances along the ecliptic for the remainder of the year. The opposition of the planet will occur Feb. 22, when its distance from the Earth will be 63,500000 miles, so that the conditions will not be the most favorable for observations of the planet's surface markings.

The paths of *Jupiter* and *Saturn* lie close together in Sagittarius and are shown on the chart with that of Mars. Both planets move eastward for three months, retrograding for four months then advancing for five months. Jupiter will overtake Saturn Nov. 28, when the apparent distance between the two great planets will be only 27′, a little less than the apparent diameter of the Moon, Saturn being north of Jupiter.

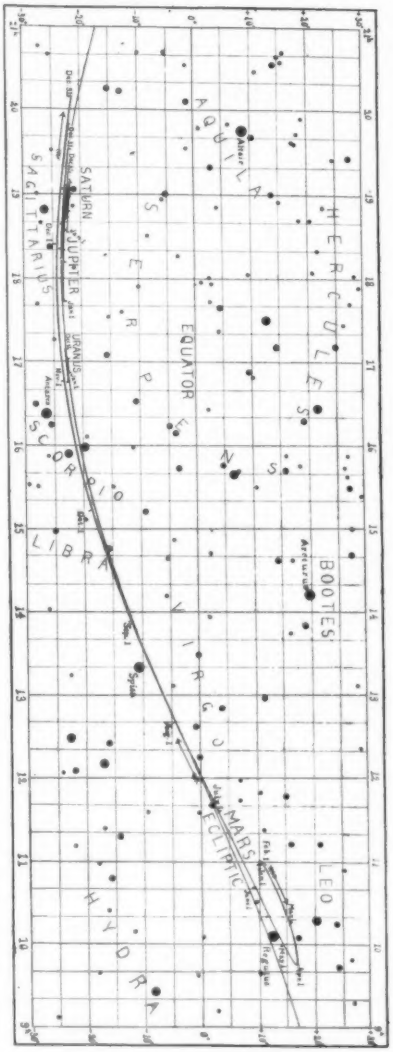
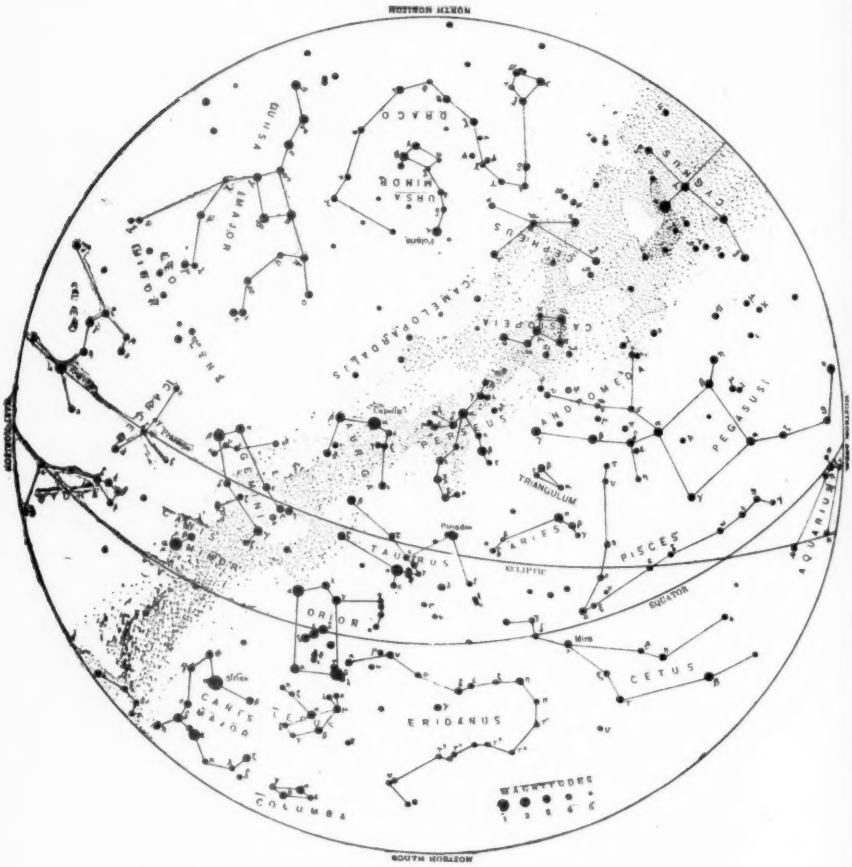


FIG. 2. CHART OF THE APPARENT PATHS OF MARS, JUPITER, SATURN AND URANUS DURING 1901.

The path of *Uranus* is shown upon the same chart a little way west of Jupiter, in the constellation of Scorpio. The path is of the same character as those of Jupiter and Saturn.



THE CONSTELLATIONS AT 9 P. M., JANUARY 1, 1901.

Neptune has a very short course at the feet of Gemini, moving westward from Jan. 1 to March 8, then eastward until Oct. 4 and westward again until the end of the year.

COMETS.

Three periodic comets are expected to return to perihelion during this year, but it is doubtful whether any of them will be seen.

1. Brorsen's Periodic comet is due at perihelion, early in January, but it has not been observed since 1879, although some of the later oppositions were equally favorable with the one which occurred in that year. The position of the comet, provided the orbit has been unchanged, is very favorable for its re-discovery this year. An ephemeris, published in the last number of POPULAR ASTRONOMY, shows that the comet should be in position to be observed by northern observers after the first of January, and that its theoretical brightness should be several times greater than at previous oppositions. The observations in 1873 and 1879

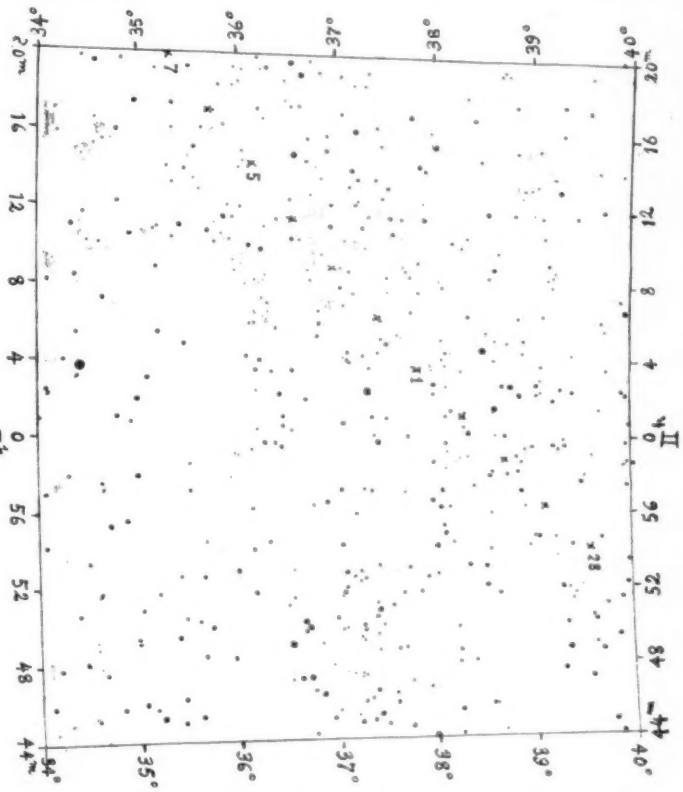


FIG. 3. CHART OF EROS FROM DEC. 28, 1900 TO JAN. 7, 1901.

seemed to indicate however a decrease in the brightness of the comet, and so like some others it may be forever lost to sight while still moving in practically the same path.

2. Denning's comet, 1894 I, is due at perihelion in June. It also will be pretty well behind the Sun, but may possibly be observed in July and August. At best it will be only a faint telescopic object, seen at a low altitude in the western sky in the evening.

3. Enckes' comet with a period of 3.3 years, comes to perihelion in September, but at that time will be almost exactly behind the Sun. It will not be in very favorable position for observation at any time during this return.

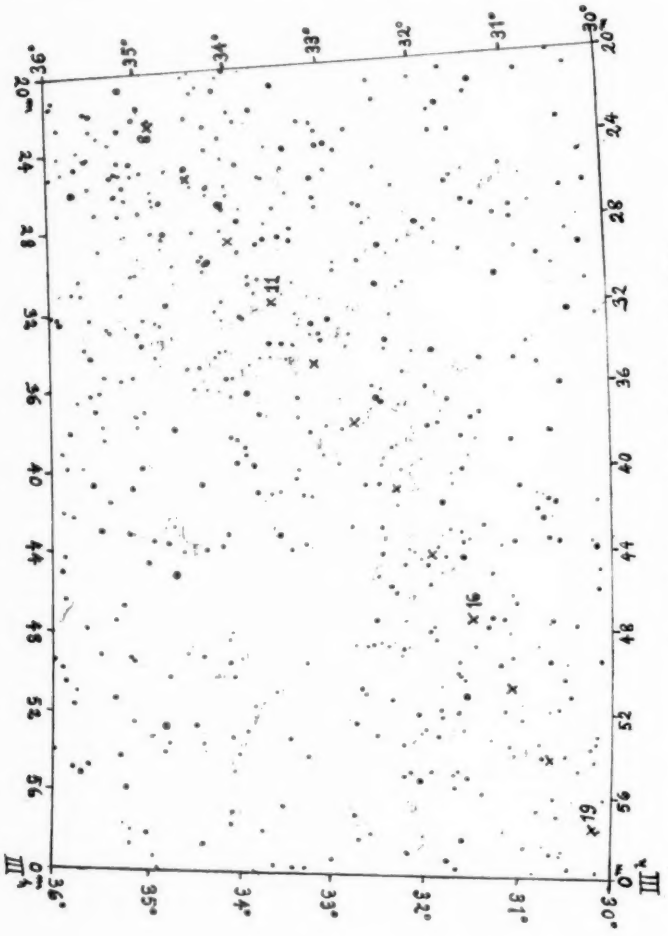


FIG. 4. CHART OF EROS FROM JAN. 8 TO 19, 1901.

ASTEROIDS.

The asteroids whose orbits have been calculated, so that they have received permanent numbering, now number 456, the last to receive numbers being the following:

(452) 1899 *FD* discovered by Keeler, Dec. 6, 1899.
(453) 1900 *FA* " " Charlois Feb. 22, 1900.
(454) 1900 *FC* " " Schwassmann Mar. 28, 1900.
(455) 1900 *FG* " " Wolf-Schwassman May 22, 1900.
(456) 1900 *FH* " " Wolf-Schwassman June 4, 1900.

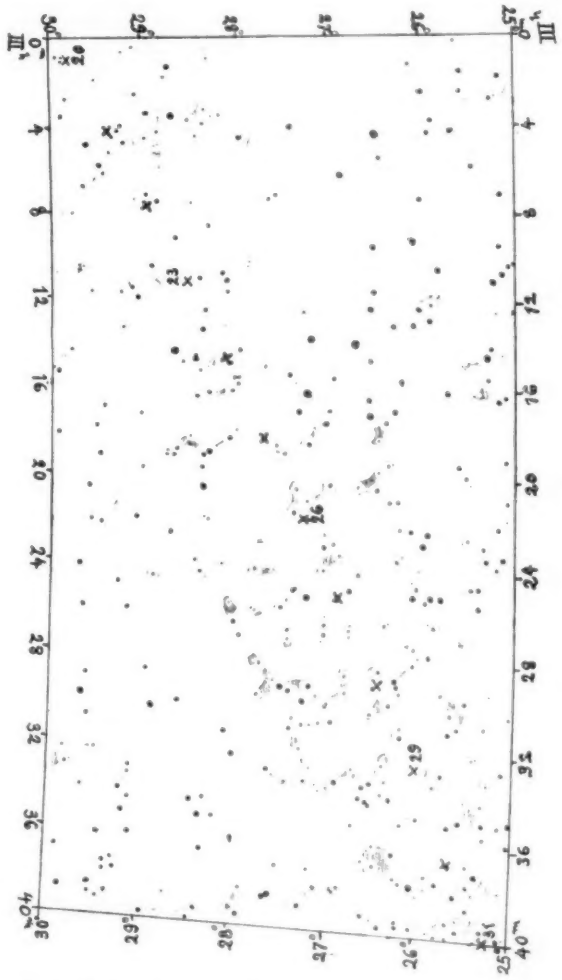


FIG. 5. CHART OF EROS FROM JAN. 20 TO 31, 1900.

Since these eleven others have been discovered, the latest announced being 1900 *FS* discovered by Wolf, Oct. 31. Some of these have been found to be identical with those previously known. The number of really new ones discovered

during the year will doubtless be as great as 10 or 12, and we may expect a like number to be found during the coming year.

The greatest importance attaches just now to the asteroid (433) Eros, because of the simultaneous observations being undertaken in nearly all the prominent Observatories, for the purpose of determining the parallax of this tiny body, insignificant in itself but very important as a means of determining the distance of the Sun more accurately than by any other known means. The planet was at opposition Oct. 30, but did not reach its point of nearest approach to the Earth until Dec. 26, when the distance was only 0.315 of the Earth's distance from the Sun, or 29,300,000 miles.

The planet continues to approach the Sun until Feb. 7 and as its distance from the Earth increases very slowly after opposition it will continue to be observed for parallax for a couple of months yet. The accompanying charts, Figs. 3-5, show the course of Eros among the stars during January. These charts are taken from a small pamphlet on the Planetoid Eros by P. Stroobant adjunct astronomer at the Royal Observatory of Belgium.

Meteors.

The Leonid shower, from the past two years' experience, does not promise to be very remarkable, still it will be possible no doubt to observe a few, perhaps dozens, of meteors from the radiant in Leo on the nights of Nov. 13 to 16, the maximum being most probable on the morning of Nov. 15.

The following is a list of the more brilliant of the other showers of the year:

	Radiant.		Meteors.
Date.	R. A.	Decl.	
Jan. 2	230°	+ 53°	Swift; long paths.
April 20	270	+ 33	Swift.
May 6	338	— 2	Swift; streaks.
July 28	339	— 12	Slow; long.
Aug. 10	45	+ 57	Swift; streaks.
Oct. 18	92	+ 15	Swift; streaks.
Dec. 10-12	108	+ 33	Swift; short.

The Perseid shower, with a maximum Aug. 10 lasts for a considerable period of time and the radiant exhibits a motion to the E. N. E. among the stars. The position of the radiant, according to W. F. Denning, on July 19 is R. A. 19°.7; Decl. + 50°.9, and on Aug. 16 is R. A. 52°.6; Decl. + 58°.5.

Occultations.

The *American Ephemeris* gives a list of 100 occultations of stars by the Moon which will be visible throughout the United States, and we will give the list month by month in Popular Astronomy. The list for January is as follows:

Date. 1901.	Star's Name.	Magnitude.	IMMERSION. Washington M. T.		Angle from N pt.	EMERSION. Washington M. T.		Angle from N pt.	Duration.
			h	m	°	h	m	°	h m
Jan. 1	ω Tauri	4.6	10	56	120	12	01	235	1 06
3	22 Geminorum	7.2	19	06	104	19	53	283	0 47
4	W. B. 7h 685	6.2	19	31	91	20	17	299	0 46
6	α Cancri	4.3	8	21	88	9	23	302	1 02
6	κ Cancri	5.0	14	51	151	16	01	266	1 10
15	B.A.C. 5395	7.0	13	24	122	14	15	262	0 51
17	14 Sagittarii	5.9	18	28	143	19	13	219	0 45
22	44 Aquarii	5.9	6	30	11	7	06	298	0 36
27	ρ^1 Arietis	7.0	6	54	61	8	14	268	1 19
27	ρ^3 Arietis	5.5	8	30	359	8	46	336	0 15
27	50 Arietis	6.8	10	08	68	11	13	276	1 05
27	53 Arietis	6.3	13	19	135	13	52	215	0 34
28	B.A.C. 1242	6.6	11	06	71	12	09	287	1 03
30	χ^1 Orionis	4.8	13	58	157	14	33	227	0 35

SPECTROSCOPIC NOTES.

The appointment of Professor Campbell as director of the Lick Observatory to succeed Professor Keeler is a fitting recognition of his eminent contributions during his connection with that institution to spectroscopic astronomy, in his study of the spectra of the Wolf-Rayet stars, in his investigation of the atmosphere of Mars, in his search for variations in the spectrum of the nebula of Orion, and especially in his measurement of velocities of stars in the line of sight and consequent detection of so many variable velocities.

It is gratifying to learn from a dispatch printed in *Science*, Dec. 14, that the completion of Professor Campbell's work on star motions with the Mills spectrograph by extending it to the southern stars has been made possible by a promise on the part of the donor of the spectrograph of a substantial sum of money to defray the expenses for two years of an expedition to South America or Australia.

It is announced that M. Paulsen has gone to Finland to continue the valuable series of observations of the aurora and its spectrum which he secured in Iceland.

Announcement is made in *Science*, December 14, of intended appointments to two new positions on the staff of the Yerkes Observatory, the holders of which will be expected to devote the principal part of their time to the measurement and reduction of photographs of star spectra. The statement that a specified number of hours per day must be given to the duties would seem to indicate that the method of the time-book is to be introduced by the Observatory management in reckoning with assistants. Outside of the hours devoted to measures and reduction opportunity will be given to become familiar with the investigations in progress at the Observatory and perhaps to take part in them.

The Royal Society has expressed its appreciation of eminent spectroscopic work in electing Sir William Huggins President.

Professor Campbell and Mr. Wright report (*Astrophysical Journal*, November) the discovery of nine stars with variable motion in the line of sight. Approximate measures are given for κ Pegasi. The list also includes the principal component of the historical visual binary ξ Ursæ Majoris.

Professor Deslandres describes in the *Comptes Rendus*, Oct. 22, his attempts to find a way of observing the corona without an eclipse by studying its infrared radiation. Observing with the assistance of M. Charbonneaux in Spain at the eclipse of May, 1900, he found the coronal radiation near the wave-length 1.3μ appreciable, half or a third that from the clear sky. Since then, modifying his apparatus slightly, he has found on examining the region close to the Sun's edge that this same radiation at 1.3μ is regularly slightly stronger at the Sun's equator than at the Sun's pole. If it can be assumed that the diffused light of the sky is distributed uniformly close to the Sun, the difference observed would be explained, particularly now at sun-spot minimum, by unequal radiation from the corona, stronger at the Sun's equator than at the poles.

VARIABLE STARS.

J. A. PARKHURST.

NO EPHEMERIS of variable stars for 1901 is yet to hand. Dr. Hartwig's is usually published about this time in the year, in the *Vierteljahrsschrift*, but part 3 of Vol. XXXV, which has just appeared does not contain it.

SS CYGNI.—The chapter of surprises from this star is not yet finished. A short maximum, probably of the same anomalous form as that of Nov.-Dec. 1899, (see POPULAR ASTRONOMY Jan. 1900, and *Astrophysical Journal* Nov. 1900, page 278) was passed the last week in October, quite well covered by the following observation of Daniel, Parkhurst, Sperra and Yendell.

	Mag.		Mag.
1900, Oct. 20.60	11.30 P	Oct. 24.67	10.44 D
21.61	11.37 D	25.50	10.75 P
22.78	11.19 D	25.92	10.3 (very poor)
24.49	10.39 D	26.50	11.08 P
24.56	10.4 Y	27.60	11.4 S

Unfortunately no observation is at hand for Oct. 23, so it cannot be positively asserted that the maximum was of the anomalous form.

This stunted maximum seemed to have a slight retarding effect on the following maximum, which was of the usual "long" type. The rise began 1900, Nov. 4 and normal light was reached about Nov. 24, the star was therefore above normal light about 20 days, one day longer than the average for this type. Full returns are not at hand for this maximum, so particulars will not be given at present. The interval since the last maximum of this type was 128 days, about 10 days longer than the average.

NEW VARIABLE STARS.

The following notices of discovery are taken from Nos. 3669-70-7 of the *Nachrichten*:

NEW VARIABLE STAR CYGNI.—(From *A. N.* 3660). On the 4th of May a star of the 9th magnitude, not in the BD, was entered in the chart for RT Cygni. At the second comparison on the 15th of September, no trace of it could be seen in the 9-inch, so that I at first thought the position of a neighboring star had been entered wrong. But a faint star appeared at the place Sept. 20, and rapidly increased in brightness, so that no doubt of the variability remained.

By comparison with BD. $+48°2950$ the position of the new variable was provisionally determined for 1900:

R. A. $19^h\ 43^m\ 19^s$, Decl. $+48°\ 49'.3$.

A 12th magnitude star follows it about 3^s, about $50''$ south.

The light change includes at least 4 magnitudes; an approximate value of the period can be determined by the maximum now approaching, it appears to be not very long ($250^d \pm$).

JOS. HISGEN, S. J.

VALKENBURG OBSERVATORY,
1900, Oct. 12.

NEW VARIABLE STAR IN LYRA.—(From *A. N.* 3670). The approximate place of this star for 1855 is:

R. A. $18^h\ 32^m\ 51^s$, Decl. $+ 43°\ 49'.6$.

There are several small stars near this place, but the diagram will show clearly the position of the variable, which at maximum attains a (photographic) magnitude of about 10½, and at minimum descends below 12 magnitude.

Below are the estimated magnitudes derived from photographs taken with a 4.4-inch portrait lens. In making these estimates, the photographic magnitude of the star just south preceding the variable was assumed to be 10.5, and that of the star midway between, BD. + 43°3025 and BD. + 43°3029 to be 11.0.

Date.	Time h	Mag.	Date.	Time h	Mag.
1899, Sept. 28	12	12.0	Sept. 18	14	11.6
Dec. 31	6½	10.9	19	13½	11.9
1900, Sept. 2	14¼	10.8	21	13½	12.0
3	14¼	10.65	23	13½	<12

It would appear from the above observations that the star was at a maximum a day or two later than Sept. 3, 1900; and that it was near a maximum on Dec. 31, 1899. There is no certain trace of the star on the last plate, although stars down to about 12 magnitude are distinctly shown.

HOVE, 1900, Oct. 2. A. STANLEY WILLIAMS.

NEW VARIABLE STAR IN PEGASUS.—(From *A. N.* 3670). At a place whose coördinates for 1855 are:

R. A. $22^h\ 4.6^m$ Decl. $+ 13°\ 38'$

there is a star not included in BD. whose variability has hitherto escaped notice. It was first seen by me either in September or October of last year. I did not then estimate its magnitude exactly, but contented myself with noting that it was brighter than BD. + 13°4863, but fainter than 4865, a somewhat lax definition, for, although these stars are both $9^m.6$, according to the BD., 4863 is really 0.4 fainter, and 4865 (which is A. G. Leipzig I 8855) $0^m.4$ brighter than that magnitude. On 1899, Nov. 6 and 1900, Sept. 2 it was invisible in a 3-inch refractor, although I could see a $10^m.2$ star not contained in the BD. whose place for 1855 is $22^h\ 4.^m6$, + 13° 51′; but on the first of this month it was again visible with a magnitude of 10.4, and yesterday I found it had risen to 9.9 magnitude, that is to say to an equality with 4863. THOMAS D. ANDERSON.

EDINBURGH, 21 EAST CLAREMONT ST.,
1900, Oct. 16.

NEW VARIABLE STAR IN LYRA.—(From *A. N.* 3671). The approximate place of this star for 1855 is:

R. A. $18^h\ 54^m\ 22^s$, Decl. $+ 34°\ 45'.5$.

The following are the estimated magnitudes derived from photographs taken with a 4.4-inch portrait lens:

1899, Sept.	2	9.6	1900, Sept.	19	9.8
	22	10.5		21	10.0
	28	11.0		23	10.0
Dec.	31	10.4		25	9.8
1900, Sept.	2	9.3	Oct.	14	9.9
	3	9.3		21	10.4
	18	9.6			

The variable is easily found, as it precedes the ($9^m.4$) star BD. 34°3385 by 16^s and is about 45″ north of the latter. A. STANLEY WILLIAMS.

HOVE, 1900, Oct. 23.

HAGEN'S ATLAS OF VARIABLE STARS.

The most important recent event in the variable star world is the appearance of Series III of Hagen's "Atlas Stellarum Variabilium" containing charts and catalogue sheets of the fainter variable stars between + 25° and + 90° declination. This series contains 37 charts, and as they are in better position for observation by northern astronomers than the preceding series, a list of the stars will be of interest.

103	T Andromedæ	1981	S Camelopardalis	5504	S Coronæ
107	T Casssiopeæ	2013	U Aurigæ	5667	R Coronæ
112	R Andromedæ	2258	V Aurigæ	5675	V Coronæ
243	U Cassiopeæ	2478	R Lyncis	5950	W Herculis
432	S Cassiopeæ	3477	R Leonis Minoris	5955	R Draconis
678	U Persei	3825	R Ursæ Majoris	6512	T Herculis
814	S Persei	4511	T Ursæ Majoris	7045	R Cygni
906	R Trianguli	4557	S Ursæ Majoris	7120	χ Cygni
1222	R Persei	4948	R Canum Ven.	7192	Z Cygni
1623	T Camelopardalis	5157	S Bootis	7428	V Cygni
1855	R Aurigæ	5190	R Camelopardalis	7779	S Cephei
1923	S Aurigæ	5237	R Bootis	8068	S Lacertæ
				8153	R Lacertæ

GENERAL NOTES.

Leonids at Jamaica Plain, Mass.—The observations of the Leonids at Jamaica Plain, Mass., given in our last number should have been credited to Robert M. Dole.

William R. Brooks whose name is so familiar to many of our readers, now has the chair of Astronomy at Hobart College, Geneva, N. Y., in addition to his duties as director of Smith Observatory at the same place.

Projection from Limb of Mars.—While observing Mars at Lowell Observatory on December 8, A. E. Douglass saw a projection on the north edge of Icarium mare which lasted seventy minutes. The region of Icarium mare is numbered 283 on the map of the surface markings of Mars in Mr. Lowell's book on Mars.

Observations According to the Eros Programme by the U. S. Naval Observatory.—Evening and morning observations and at occasional times during the night have been made on every clear night since the first of October. The observations are made in rectangular coördinates, and whenever possible referred to two stars.

On the meridian circle observations of the comparison stars for the photographic plates are somewhat more than half finished for the first group published. The intention is to secure two observations for each star clamp east and clamp west, but we have had so much cloudy weather that it is doubtful if we can finish the second half of the list published in Circular No. 5.

S. J. Brown.

Leonids at Pomona College, Claremont, California.—After the disappointment of last year, when an organized force of over fifty observers was trained for a campaign of at least a week, with charts and tables, and three photographic stations, and were met with almost total cloudiness all the week and a general failure of Leonids to attack all along the line, the astronomy class of Pomona College entered upon the observation of Leonids this year with more quiet and modesty. The plan of observation covered every night from November

12 to 17, but the weather was so unfavorable that careful watch and record was kept only during the hours from 12 to 4 A. M. on the mornings of November 14 to 16. This time was divided into periods of half an hour each, with three or more observers for each period. One noted the time of every call, a second kept the count, while the third mapped and described as many as possible. Meteor paths were charted each night, but the limited knowledge of uranography and lack of experience on the part of the amateur observers rendered them unsatisfactory for the discussion of radiant points. Less than thirty were seen *in* Leo, and the adjacent constellations, and over thirty in Gemini, Auriga, Taurus and Orion, while nearly fifty were seen in the circumpolar constellations visible, chiefly in Ursa Major. Beside the Leo radiant there seems to be one also in Gemini between α, β, ι and τ.

The results are exhibited chiefly in the accompanying tables:

TABLE I.—DESCRIPTION OF INDIVIDUAL METEORS.

Part 1. Groups I-IV Wednesday, Nov. 14, 12-2 A. M. Observers ———.

Gr'p	No.	Location.		Length	Time.	Description.		Color.
		Constellation.	Direction			Dura.	Mag.	
			°					
I	1	Leo	270	8	12 14 00	1	−1	B
	2	Leo Minor	90	5	12 17 00	¼	4	W
	3	Ursa Minor	170	10	12 28 05	¼	0	Y
	4	Leo Minor	10	8	12 28 20	¼	4	W
	5	Ursa Major	145	5	12 29 22	½	2	Y
II	6	Ursa Minor to Draco	130	10	12 35 15	5	1	Y
	7	Ursa Major	85	5	12 42 30	¼	4	W

TABLE II.—RESULTS OF OBSERVATION BY PERIODS.

Date Nov.	No.	Time Begin.	Time End.	No. of Meteors	No. of Leonids	Field.	Weather.
14	I	12:00	12:30	5	3	East	Clear
"	II	12:30	1:00	5	2	"	"
"	III	1:00	1:30	3	3	"	"
"	IV	1:30	2:00	11	3	"	"
"	V	2:00	2:30	7	5	E, N & Z	"
"	VI	2:30	3:00	2	2	"	"
"	VII	3.00	3:30	5	5	Whole Sky	"
"	VIII	3.30	4:00	9	4	"	"
15	IX	12:00	12:30	1	0	N & E	Cloudy except near the zenith
"	X	12:30	1:00	0	0	"	
"	XI	1:00	1:30	2	1	"	
"	XII	1:30	2:00	4	1	"	
"	XIII	2:00	2:30	3	2	.....	
"	XIV, XV, XVI	2:30	4:00	0	0	.....	Cloudy
16	XVII	12:00	12:30	8	1	Whole Sky	"
"	XVIII	12:30	1:00	15	5	"	"
"	XIX	1:00	1:30	13	2	"	"
"	XX	1:30	2:00	13	6	"	Hazy E. & S.
"	XXI	2:00	2:30	6	1	R, N & Z	Hazy
"	XXII	2:30	3:00	3	0	"	More Hazy
"	XXIII	3:00	3:30	4	2	"	" "
"	XXIV	3:30	4:00	1	1	"	Cloudy
				120	49		

TABLE III.

Nov. A. M.	Total No. of Meteors.			No. of Leonids.		
	14th	15th	16th	14th	15th	16th
12:00-12:30	5	1	8	3	0	1
12:30- 1:00	5	0	15	2	0	5
1:00- 1:30	3	2	13	3	1	2
1:30- 2:00	11	4	13	3	1	6
2:00- 2:30	7	3	6	5	2	1
2:30- 3:00	2	0	3	2	0	0
3:00- 3:30	5	0	4	5	0	2
3:30- 4:00	9	0	1	4	0	1
Total	47	10	63	27	4	18

The whole number would, of course, have been much larger if there had been no moonlight. For the twenty periods during which any were seen, the average interval was five minutes; for the three periods from 12:30 to 2:00 Friday morning, it was $2^m\ 12^s$. Twice, a little before two o'clock, two were seen at once and there were thirteen intervals of less than one minute. During all the remainder of the time there were only seven such intervals. Any attempt, however, to discuss the frequency of fall must be unsatisfactory because of the haze and cloudiness at times. More might have been seen during the later periods of the 15th and 16th if the sky had been clear, and the larger numbers in the second, third and fourth periods of the 16th may have been due to the absence of moonlight, yet the order of results is probably correct, and indicates that the greatest number fell on the 16th, and the least on the 15th. The large proportion of non-Leonids is noticeable.

About seventy-five, or three-fifths of the meteors observed, were between the second and fourth magnitudes, twenty were of first magnitude and higher, six of class — 1 and one, — 2.

Three-fourths were either white or yellow, in about the same proportion, and about five each of blue, orange and red.

The duration of half were too swift for estimation, and nearly fifty more were seen for less than one second. Only five were visible for more than one second.

Both duration and length of path were doubtless shortened by moonlight and cloudiness. A course of some 30° and over was traced for about 20; from 15° to 20° for about 30; some 10° for about 50, and a shorter course of 5° or 6° and less for about 20.

KEY TO TABLES.

Table I. Description of individual meteors.

Designation: Group I, II, etc., half hour periods throughout the week.

Nos. 1, 2, 3, etc., individual number; new count begun each night.

Location: Constellation in which seen.

Direction by position angle.

Length of path, in degrees.

Description: Time (S. P. T.) of appearance.
Duration in seconds, or if swift, *s.*
Magnitude.
Color, by initial letter.

Table II. Results by periods.
Date, civil time.
Number of period.
Time of beginning and end of period.
Number of meteors counted.
Number of Leonids.
Field, portion of sky observed.
Weather.

Observations of the November Meteors.—On the 12th and 14th of November, 1900, I watched until sunrise and on the 13th until one o'clock, when it became cloudy. During a watch of two hours on the morning of the 16th, no Leonids were seen and the work was then discontinued.

Altogether, on the four nights, thirty meteors were seen near the constellation Leo, of which only ten were Leonids, the others being principally Geminids, Taurids and Orionids. The trails were carefully plotted and the exact time of appearance was recorded; the results with the ten Leonids are as follows:

Washington Mean Time Civil Day.	Beginning of Trail.		End of Trail.		Mag	Motion.	Color.	Trail.
	R. A.	Decl.	R. A.	Decl.				
d h m s	h m	°	h m	°				
13 0 45 32	10 1.0	+ 18.8	10 13.0	+ 14.7	2	slow	yellow	none
1 6 26	10 14.2	18.8	11 4.2	7.0	2	medium	yellow	none
2 44 54	*9 44.0	24.0	10 24.0	31.0	2-3	rapid	blue-yel	none
15 0 20 8	10 1.0	25.6	10 18.5	35.7	3	rapid	blue-yel	none
0 29 31	10 3.2	24.5	10 44.2	31.8	2½	rapid	bluish	slight
0 57 35	9 51.1	17.2	9 52.0	9.0	1	medium	blue-yel	none
1 0 22†	*9 30.8	21.4	8 48.6	22.8	3	medium	blue	none
1 52 46	10 24.2	40.8	10 46.4	49.0	1	medium	blue-yel	**
1 24 25	9 58.5	17.9	10 1.5	6.6	1½	medium	yel-red	trail
3 16 22	*9 37.3	+ 22.6	9 36.0	+ 30.7	2	rapid	yellow	slight

† Somewhat doubtful because seen distinctly only over latter part of path.

** A very long trail persisting for a second or two.

The three meteors marked with an asterisk apparently do not proceed from the same radiant as the other seven. The approximote positions of the two radiants are:

Leonid radiant (from seven meteors) R. A., 148° 10′; Decl., + 23° 0′
Leonid radiant (from three meteors) R. A., 144° 0′; Decl., + 21° 50′

In order to ascertain whether the present path derived from these observations is greatly different from that pursued by the swarm hitherto the elements of the orbit were computed from the first of these radiant points. These elements are, of course, merely those of the part of the swarm encountered by the Earth. The principal change, aside from the progressive motion of perihelion, seems to be in the inclination, which is here 29′ larger than found by Adams. The values of q and e are almost identically the same.

$i = +163°\ 43'$	$\pi = +\ 45°\ 30'$	Perihelion distance	0.9862
$e = 0.9046$	$\Omega = +230\ \ 37$	Aphelion distance	19.6942

These results have, however, but little or no value as they are derived from so few observations, and they throw no light on the present path of the *densest part* of the swarm. ERIC DOOLITTLE.

THE FLOWER OBSERVATORY,
Philadelphia, Nov. 20, 1900.

Professor Francis E. Nipher has prepared three interesting papers on the following themes: "The frictional effect of railway trains upon the air,', "On temperatures in gaseous nebulæ," and "On positive photography with special reference to eclipse work." The last is reprinted in this number.

Annuaire Astronomique for 1901 by Camille Flammarion, has already appeared. It is a useful volume of 207 pages, fully illustrated with a complete list of the astronomical phenomena belonging to the new year on which we have entered.

Calculus with Applications is the title of a new book by Ellen Hayes, Professor of Applied Mathematics in Wellesley College. The publishers are Messrs. Allyn & Bacon, Boston, 1900.

This little book of 162 pages has for its object aid to two classes of students: Those who wish, for purposes of culture, to know what the calculus is and what it is for; and also those engaged in work in chemistry, astronomy, physics, economics, etc., who have not the time to pursue the fuller courses of the differential and the integral calculus which are such a delight to the pure mathematician.

This book is designed, therefore, as a reading lesson in applied mathematics, and such examples are chosen, for the most part, as are real problems from some of the branches of study named above. One of the leading thoughts of the author is, that the student should not be held, too long, on examples illustrating the principles of the calculus, lest it beget "indifference, discouragement and despair." And yet he must be made thoroughly familiar with these principles or he will be unable to use the "fine tool" of the calculus with a degree of knowledge that will assure certainty of result. There is no doubt but that the golden mean between these two ideas is that which is sought and most earnestly coveted by every true instructor who serves the highest good of his students in his daily class drills.

The first chapter deals in elementary way with the differentiation and the integration of algebraic functions. There is advantage in treating the two converse processes side by side as this author does. We wonder that more writers do not pnrsue the same course in the elementary parts of text books. Our eye falls on one rather unfortunate statement on page 12 if we catch the author's meaning. It is that "integration is largely a matter of guess work and experiment." A mathematician will get the meaning, but a novice might be misled by it, in supposing that the process involves uncertainty which does not really belong to it.

The remaining part of the chapter presents the rules for implicit, trigonometric, exponential and other transcendental functions, partial and successive differentiation, the Taylor, Maclaurin and Binomial theorems, series and indeterminate forms. In 34 pages we have a concise and clear presentation of subject matter that is usually spread over more than twice the space here given.

In the next chapter comes the study of the graph and maxima and minima in the Cartesian and the polar systems of coordinates with examples for illustration. The remaining three chapters are devoted to applications, analytic geometry and a collection of useful formulæ.

Under applications is given about sixty pages of excellent matter. We have ourselves been so interested in it that we have read it with pleasure and profit. We will use this book as reference in some particulars for classes who will pursue the calculus for a whole year, the last term of which is given, wholly to the work of application to the branches already named.

Durfee's Elements of Trigonometry.—This new book on the elements of trigonometry is written by William P. Durfee, professor of mathematics in Hobart College, and published by Messrs. Ginn & Company, Boston, Mass. It contains 105 pages, and presents in seven chapters the usual matter pertaining to this branch of mathematics with some things added that are especially useful for the student to know in his study of this and kindred branches of the mathematics. One of those things is the first chapter of the book which treats of computation. In this the author first deals with the idea of measurement, and draws attention to what accurate measurement means, and how it is obtained to some approximate degree. This is illustrated in finding the square root of 2. The first result is 1.4, correct to the tenth's place, then 1.41, nearest to the hundredths, 1.4142, an approximation to the ten thousandths' place. The square of these numbers shows how results of a greater number of places of decimals approximate the true value of the square root of 2. Generalization then follows in similar remarks that apply "to all surds, to nearly all logarithms, to π, and to the various trigonometric ratios." Useful remarks follow about taking the sums of numbers wherein approximate answers only can be obtained on account of some conditions affecting the quantities to be added in different ways; the same with regard to much of the ordinary arithmetical processes with which the ordinary student has to do in the daily preparation for the class-room work.

Further illustrations of labor-saving ways are suggested in regard to computations involving the use of logarithmic tables, that will help beginners very much. At the close of this chapter some remarks are made which set forth the author's ideas in this matter in clear and effective way. He says: "Accuracy in computing can be obtained only by practice and by constant care. When the computer has made his interpolation he should glance back at the table and see that his result lies between the proper tabular numbers and nearest to the right one. This takes but an instant and corrects many errors. The importance of carefully planning a computation before entering upon it can scarcely be overestimated. The plan should be written out. The computer is then free to devote his whole attention to the mechanical details of the work. Paper ruled in squares conduces to accuracy. If the computation be confined to one column, it can be repeated, or a similar one inserted in a parallel column without repeating the plan. If any given number occurs repeatedly in a computation, it may be written down once for all on a separate piece of paper and held over any number with which it is to be combined.

"The computer will avoid many errors if he accustoms himself to making rough estimates of results; when the nature of subject permits, these estimates may be obtained by *graphic* methods.

"To insure accuracy the computer must continually check his work. Every operation, every step in every operation must be tested before going on."

All this is so important in the early training of students that it is emphasized much by teachers who have had some experience as computers. These things and many others like them are constantly and habitually used by all practical and experienced computers. They could not trust themselves to do any work without such safeguards. If the courses of training in public schools and colleges were prosecuted with such methods as these with rigid faithfulness, nine-tenths of the pupils or students leaving these schools would be able to perform ordinary arithmetical operations *without making so many mistakes habitually* as to cause them to feel uncertain of the accuracy of any result however simple the process. As Parson Brownlow used to say: "This sin is butt-cut of all," and many instructors are responsible for it more than they willingly will confess.

The new little book will interest teachers.

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